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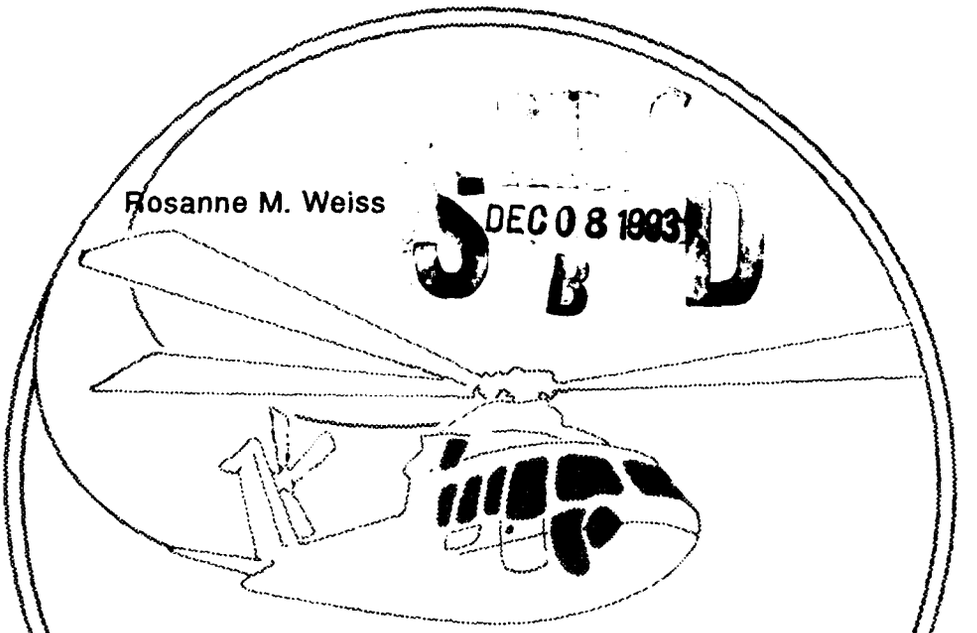
Combined 1991 and 1992 Robinson - 22B (R-22) Parking Test Results

Rosanne M. Weiss



September 1993

DOT/FAA/CT-TN93/6

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16. Abstract

Tests were conducted in the fall of 1991 and 1992 at the Federal Aviation Administration (FAA) Technical Center to examine issues regarding rotor tip clearances for parking areas at heliports. These tests were initiated as a follow-on to previous parking tests documented in DOT/FAA/CT-TN88/30, "Heliport Surface Maneuvering Test Results," and DOT/FAA/CT-TN/92/1, "Helicopter Nighttime Parking Test Results-UH-1." Since those tests utilized a medium-size helicopter with a rotor diameter of 48 feet, similar tests were requested using a smaller helicopter with a rotor diameter of less than 30 feet.

This report documents the results of these follow-on parking tests which used a Robinson-22B (R-22) helicopter. Over 480 maneuvers were conducted at the FAA Technical Center's National Concepts Development and Demonstration Heliport/Vertiport, Atlantic City International Airport, NJ. All were conducted under head, tail, and crosswind conditions, both with and without an obstacle on the helipad. Pilot subjective data, in reference to these maneuvers, were collected via post-maneuver and post-flight questions.

Data collection and analysis methodology and objective, as well as subjective issues, are discussed. Statistical and graphical analysis of pilot performance and perception data are provided. Conclusions are drawn about considerations that must be given to parking clearance criteria at heliports.

The results will be considered in future modifications to the FAA Heliport Design Advisory Circular, AC 150/5390-2.

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EXECUTIVE SUMMARY

Tests were conducted at the Federal Aviation Administration (FAA) Technical Center to measure pilot perception and performance during helicopter parking maneuvers. These parking tests were initiated as a follow-on to previous parking tests documented in DOT/FAA/CT-TN88/30, "Heliport Surface Maneuvering Test Results", and DOT/FAA/CT-TN92/1, "Helicopter Nighttime Parking Test Results-UH-1". This work was conducted with a small helicopter, the Robinson-22B (R-22) in the fall of 1991 and 1992. Results of these tests will be used to aid in answering questions concerning heliport parking area clearance criteria. These questions deal with safe rotor tip clearances when parking near obstacles and ground clearance lines, pilot-preferred clearances, and pilot performance when parking near obstacles and ground clearance lines.

This report documents the results of this activity. In addition, it describes the data collection and analysis methodology and discusses objective, as well as subjective issues. Statistical and graphical analyses of pilot performance and perception data and subjective input are provided.

The parking procedures were conducted under head, tail, and crosswind conditions both with an obstacle and without an obstacle in place on the helipad. Pilot subjective data referring to safety, control, and workload were gathered following each maneuver. In addition, subjective data concerning pilot comfort with performing the requested procedures were collected via a post-flight questionnaire.

Forty pilots participated in the tests. These pilots were private, industry, and FAA pilots, as well as flight instructors from numerous helicopter schools. A total of 482 maneuvers were completed, 242 where the pilot was allowed to park with a tip path clearance of his own choice and 240 where the pilot was instructed to park with a fixed 10-foot (ft) tip path clearance.

Statistical data and plots indicate that the current 10 ft required clearance for an R-22 is adequate but an additional 5 ft, i.e., a tip clearance of 15 ft, would be more practical. The pilots tended to perform on the safe side when parking near either the ground reference line or the obstacle.

An examination of the pilot post-maneuver input, as well as from the post-flight questionnaires, reveals that the pilots were less comfortable with parking the aircraft under tailwind conditions. This is consistent with the results documented in both FAA/CT-TN88/30 and FAA/CT-TN92/1. Therefore, as discussed in the two previous reports, prevailing winds are a major factor in parking/maneuvering performance, as well as in pilot-perceived comfort levels when parking/maneuvering a helicopter on the heliport surface.

INTRODUCTION

PURPOSE.

Technical Notes DOT/FAA/CT-TN88/30, "Heliport Surface Maneuvering Test Results", and DOT/FAA/CT-TN92/1, "Helicopter Nighttime Parking Test Results -UH-1" addressed issues regarding rotor tip separation in ground maneuver areas at heliports. These issues included tip clearances between rotorcraft and objects or rotorcraft and ground maneuver markings.

Based on examination of those data, questions arose as to whether the performance by pilots of smaller helicopters might be the limiting factor in determining rotor tip clearance criteria at heliports. Since the previous tests were done using a medium size helicopter with a rotor diameter of 48 feet (ft), similar tests were required using a small helicopter, one with a rotor diameter of less than 30 ft. This report discusses the results of two sets of tests conducted in 1991 and 1992 using such a helicopter.

These tests addressed the following objectives:

a. Determine the safe rotor tip clearances preferred by pilots when parking a helicopter near an object.

b. Determine how well pilots can judge tip clearances when asked to park a set distance from an edge marking or an object.

c. Provide data to the Vertical Flight Program Office to aid in the verification of, or modification to, the current Heliport Design Advisory Circular (AC150/5390-2) separation criteria for parking areas.

BACKGROUND.

The focus of these tests was on the issue of rotor tip clearances as discussed in AC 150/5390-2. Section 26a of that advisory circular describes the recommended location and separation criteria for parking areas as follows: "Except for helipads and helidecks located in the final approach and take off area (FATO) or takeoff and landing area, the parking area shall be located such that parked helicopters are clear of the approach and departure surfaces and have at least 1/3 rotor diameter but not less than 10 foot (3m) clearance from a takeoff and landing area or a fixed or movable object."

This criteria is based on operational judgement. Flight test data were collected at the Federal Aviation Administration (FAA) Technical Center during the fall and early winter of 1987 under daylight visual flight rules (VFR) conditions and in January and August 1989 under nighttime conditions. From the results of those tests, questions arose concerning the amount of clearances that might be needed by the pilots who fly smaller helicopters. It is believed that the smaller helicopter might be the limiting factor concerning tip path clearance criteria during ground maneuvering and parking operations. Therefore data were collected to measure pilot performance during parking operations and to obtain pilot perception and preferences with reference to rotor tip clearances using a helicopter with a rotor diameter of less than 30 ft. These tests were conducted in September 1991 and October 1992.

METHODS

TEST AIRCRAFT.

In order to conduct this work, a Robinson-22B (R-22) helicopter was obtained through a rental agreement with a local helicopter academy. The R-22 is a two-seat single-piston engine helicopter with a low inertia rotor system. It has a rotor diameter of 25.2 ft and is capable of speeds up to 96 knots (kt), with a maximum takeoff weight of 1,370 pounds. Additional specifications can be found in appendix A.

DATA COLLECTION.

TEST LOCATION. All parking maneuvers were conducted at the FAA Technical Centers National Concepts Development and Demonstration Heliport/Vertiport, Atlantic City International Airport, NJ.

PROCEDURES. Each pilot was instructed by a safety pilot to maneuver the helicopter on the heliport under head, tail, and crosswind conditions. One-half of the maneuvers had an obstacle on the heliport, while the other half had only a ground marking for reference. The obstacle used consisted of a wooden crate placed on a trailer pulled by a minitractor. The overall dimensions of the obstacle, including tractor, wooden crate, and trailer was approximately 11 ft long, 4.5 ft wide, and 5.5 ft high.

During the first part of the test, the pilot was instructed to park parallel to the obstacle or the ground marking with a tip clearance of his choice, one he would feel was a safe clearance. When the pilot was satisfied with the helicopter's position, he was asked to estimate his actual rotor tip clearance from either the obstacle or the ground marking. Ground personnel then placed markers at the edge of the skids. Measurements of the marker locations were taken by the ground personnel after the helicopter moved to a safe location.

During the second portion of the test, the pilot was instructed to park the helicopter with a fixed 10-ft tip path clearance. Again, ground personnel positioned markers, and measurements were taken after the helicopter's departure from the landing zone. Also, following each maneuver, the pilot was asked to rate the maneuver in terms of controllability, safety, and pilot workload or demand using a modified version of the Cooper-Harper Rating Scale, as seen in figure 1.

For each phase of the test each pilot completed at least three maneuvers with the obstacle and three with only the ground marker as reference. Table 1 presents the actual wind conditions during each test period along with the number of runs flown per flight and subject pilot experience. The obstacle and ground markings on the heliport were adjusted to the wind conditions so all subjects evaluated had equivalent head, tail, and cross wind conditions.

Figure 2 shows a sample layout of the heliport as used during these tests.

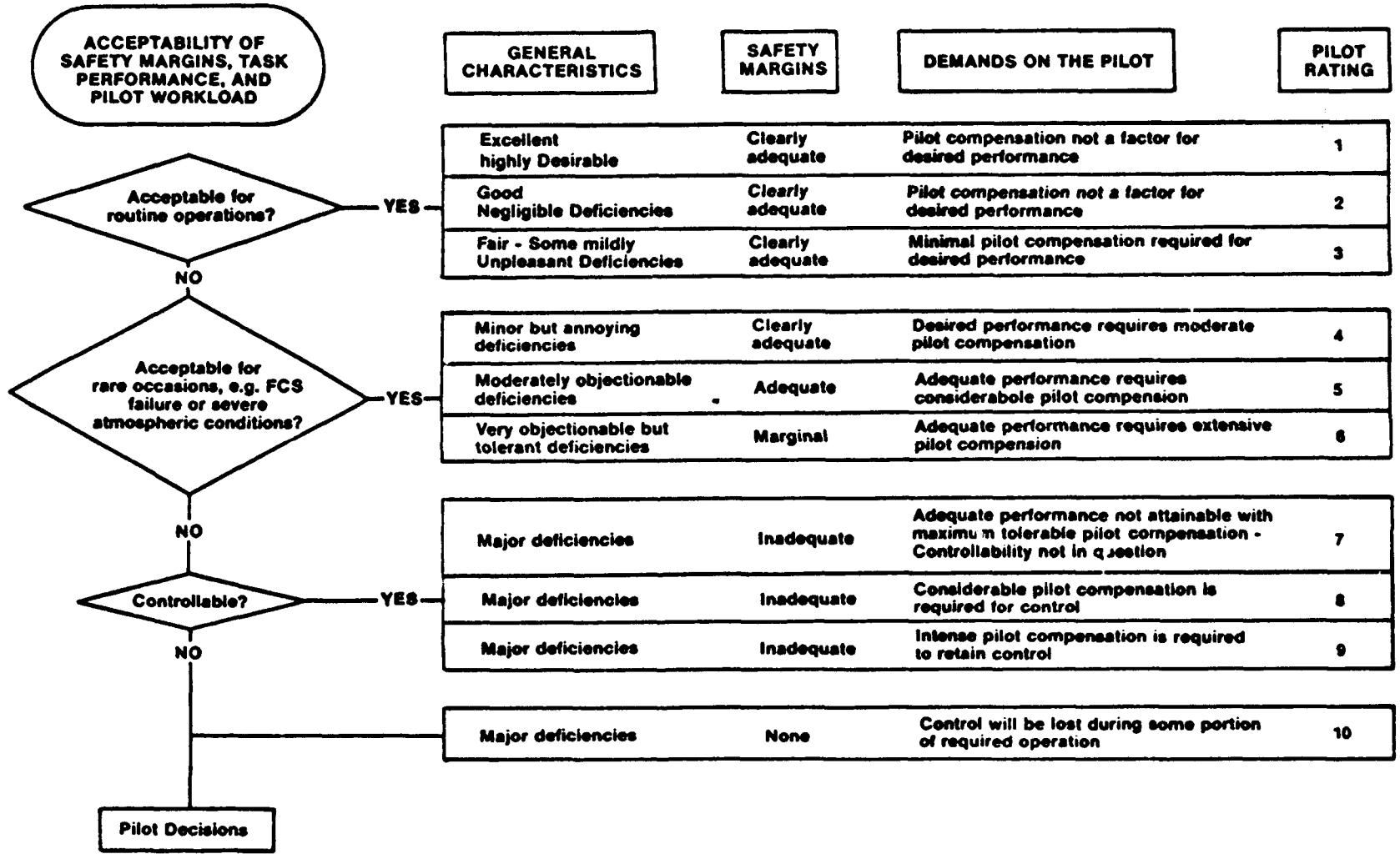

FIGURE 1. COOPER-HARPER RATING SCALE

TABLE 1. WIND CONDITIONS AND PILOT EXPERIENCE FOR R-22 PARKING TESTS

Flight Number	Wind Condition Direction (degrees)	Wind Condition Speed (kt)	Number of Runs	Subject Pilot Rotorcraft Flt Time (hour)
1991				
1		calm	12	199
2		calm	12	70
3	230-260	11-13	12	600
4	230-360	8-10	14	2850
5	340-360	5-9	12	85
6	020-050	5-7	12	315
7	030-040	5-7	12	320
8	260-280	9-12	12	150
9	250-270	6-10	12	90
10	230-250	8-11	12	418
11	210-270	8-12	12	2800
12	120-140	5-9	12	880
13	160-200	4-8	12	81
14	210-240	10-12	12	1400
15	190-240	9-18	12	1700
16	330-360	10-16	12	50
17	10-20, 330-360	10-15	12	75
1992				
1	330-360	9-10	12	110
2	250-290	4-8	12	2000+
3	250-260	10-12	12	400+
4	040-060	11-15	12	300
5	020-060	9-13	12	180
6	270-310	0-5	12	95
7	200-240	4-7	12	
8	170-180	6-10	12	380
9	160-200	8-10	12	40
10	160-180	6-17	12	5000
11	170-210	8-15	12	350
12	280-310	7-10	12	74
13	120-130	0-5	12	140
14	260-290	0-5	12	35
15	250-270	5-9	12	476
16	240-290	0-8	12	64
17	240	10-13	12	3080
18	220-270	14-18	12	162
19	310-340	12-15	12	260
20	340-350	6-11	12	700
21	300-340	5-7	12	200
22	230-250	8-15	12	9500
23	210-250	10-15	12	1350

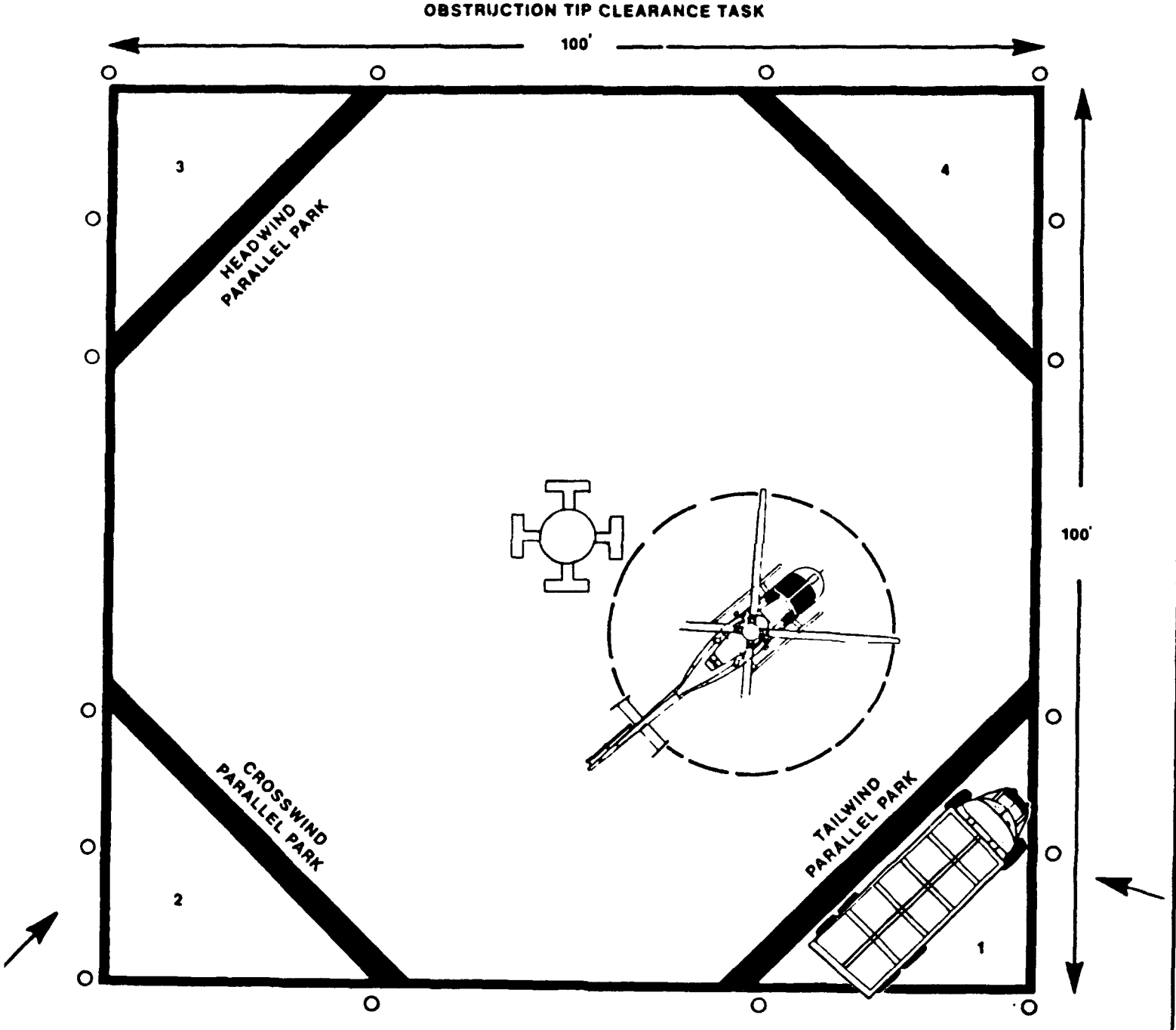

FIGURE 2. HELIPORT LAYOUT

PARTICIPANTS. Seventeen subject pilots flew the procedures in the 1991 flights and 23 in 1992. Of the 17 1991 pilots, 13 were either instructors or students from the helicopter academy from which the aircraft was rented, two were from North East Helicopters in Connecticut, one was an FAA test pilot with previous industry experience, and one was affiliated with the helicopter academy, but worked as a helicopter pilot for the New Jersey State Government. Of the 1992 subject pilots, six were either instructors or students from the helicopter academy from which the helicopter was rented, four were instructors at other helicopter schools, four were from industry, six were private pilots, one was from Helicopter Association International, and two were FAA test pilots.

Flight experience for all 40 pilots is presented in table 2, by total flight hours (hrs), total time in type, and total helicopter hrs over the past 6 months. The majority were low-time pilots, both in total flight hrs and in helicopter hrs. Their total flight hrs ranged from 35 to 2400 and their helicopter experience ranged from 35 to 9500. The median number of total flight hrs was 420 while the median number of helicopter hrs was 260. Twenty-seven percent had less than 100 hrs of rotorcraft experience with only 22 percent having more than 1000 hrs. This indicates that this group was made up primarily of low-time, relatively inexperienced helicopter pilots.

TABLE 2. SUBJECT PILOT FLIGHT EXPERIENCE

Total Flight Hours	Number of Pilots
0-500	23
501-1500	6
1501-3000	2
>3000	9

Total Helicopter Hours	Number of Pilots
0-500	28
501-1500	5
1501-3000	4
>3000	3

Total Time in Type	Number of Pilots
0-500	31
501-1500	3
1501-3000	4
>3000	0

Total Helicopter Hours Last 6 Months	Number of Pilots
<10	4
10-50	15
>50	20

DATA PROCESSING AND ANALYSIS

SOURCE OF DATA.

Data for this work came from the following sources:

a. The onboard log which included pilot clearance estimates and pilot post-maneuver ratings.

b. Ground measurements taken at the heliport.

c. Post-flight questionnaires.

ONBOARD LOG. The safety pilot was responsible for filling in the onboard log. Information recorded on this log included the following:

a. Subject-pilot estimates of the actual rotor tip clearances achieved with the given wind condition.

b. Pilots' post-maneuver ratings of the maneuvers controllability, safety, and workload or demand using the modified Cooper Harper Rating Scale.

c. Local weather and wind conditions.

A sample of this log can be found in appendix B.

GROUND MEASUREMENTS. All distances were measured from two corners of the helipad to the midpoint between two markers positioned next to each skid by the ground crew. This midpoint was considered to be the location of the aircraft's mast. The X and Y coordinates of the midpoint were calculated using simple geometric procedures. With these coordinates, it was possible to calculate the shortest distance from the mast to either the obstacle or the ground marking. The rotor tip clearance was computed by subtracting the rotor radius from that calculated distance.

POST-FLIGHT QUESTIONNAIRE. At the conclusion of the flight, each subject was given a post-flight questionnaire to complete. A sample of this questionnaire is found in appendix C. This questionnaire required the pilot to rate how comfortable he felt parking 10 ft from both the ground marking and the obstacle with different wind conditions. This questionnaire provided comparative subject pilot measures across all maneuvers. In addition, pilot background information, such as total flight hours and aircraft experience, was requested.

ANALYSIS PROCEDURES.

PARKING PROCEDURE DATA. Two types of errors were computed: perception error and performance error.

The perception errors were calculated by comparing the actual rotor tip clearances to the pilot-estimated clearances. The actual clearances were

determined by the geometric computations carried out on the ground measurements. Separate errors were calculated based on the presence or absence of the obstacle.

Performance errors were computed by comparing the actual tip path clearances to the requested 10-ft clearances. Separate errors were calculated based on the presence or absence of the obstacle.

Plots were produced for these errors for each type wind condition and for all wind conditions together. Plots of the actual tip path clearances versus perceived clearances, both with and without the obstacle, were also produced. Mean and standard deviations of the actual clearances were calculated and presented in table form for the three wind conditions, both with and without the obstacle. The error means and standard deviations are also presented in table form. These tables are presented in the Results section.

INFLIGHT/POST-MANEUVER PILOT RATINGS. The Cooper-Harper ratings given by the pilots immediately following each maneuver were tabulated. Frequency plots were produced for these ratings by grouping all similar runs.

POST-FLIGHT QUESTIONNAIRE DATA. Plots were produced to graphically depict the pilot responses for the post-flight questions referencing pilot workload comfort levels while parking under tailwind, headwind, and crosswind conditions. Responses to other post-flight questions were also tabulated.

RESULTS

PILOT CHOICE MANEUVERS.

For each of the pilot choice maneuvers, each pilot was told to park the aircraft such that his rotor tip clearance would be a safe distance from another aircraft or from the ground marking. During this phase the actual tip clearances varied from 0.21 to 23.64 ft from the ground marking and from 3.69 to 23.64 ft from the obstacle. Table 3 contains the minimum and maximum tip clearances for the pilot choice maneuvers by wind conditions. The actual data, along with the computed errors, can be found in appendix D.

Comparisons of UH-1H daytime test results vs the R-22 test results can be found in appendix E.

The means and standard deviations of their actual rotor tip clearances, regardless of wind type, with and without the obstacle, are found in table 4 and by wind type in table 5.

Figure 3 presents plots showing the number of occurrences for the actual clearances for the pilot choice maneuvers. As seen in these plots, the rotor tip never overlapped the obstacle or the ground marking. The majority of the clearances were between 5 and 20 ft.

TABLE 3. MINIMUM/MAXIMUM TIP CLEARANCE FOR PILOT CHOICE DATA

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Minimum	1.51	1.78	0.21
Maximum	20.97	23.64	20.45
Number of Subjects (N)	40	41	40
With Obstacle			
Minimum	6.86	4.53	3.69
Maximum	23.64	23.07	23.26
N	41	40	40

TABLE 4. ACTUAL ROTOR TIP CLEARANCES REGARDLESS OF WIND TYPE (PILOT PREFERENCE)

In Feet

	Without Obstacle	With Obstacle
Mean	10.02	12.10
Standard Deviation (SD)	4.77	4.62
N	121	121

(The clearance criteria for an R-22 is 10 ft)

TABLE 5. ACTUAL ROTOR TIP CLEARANCES BY WINDS (PILOT PREFERENCE)

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	9.94	10.84	9.26
SD	5.04	4.70	4.55
N	40	41	40
With Obstacle			
Mean	13.21	11.47	11.60
SD	4.44	4.64	4.70
N	41	40	40

(The clearance criteria for an R-22 is 10 ft)

Pilot's Choice Data W/O Obstacle
Actual Clearance

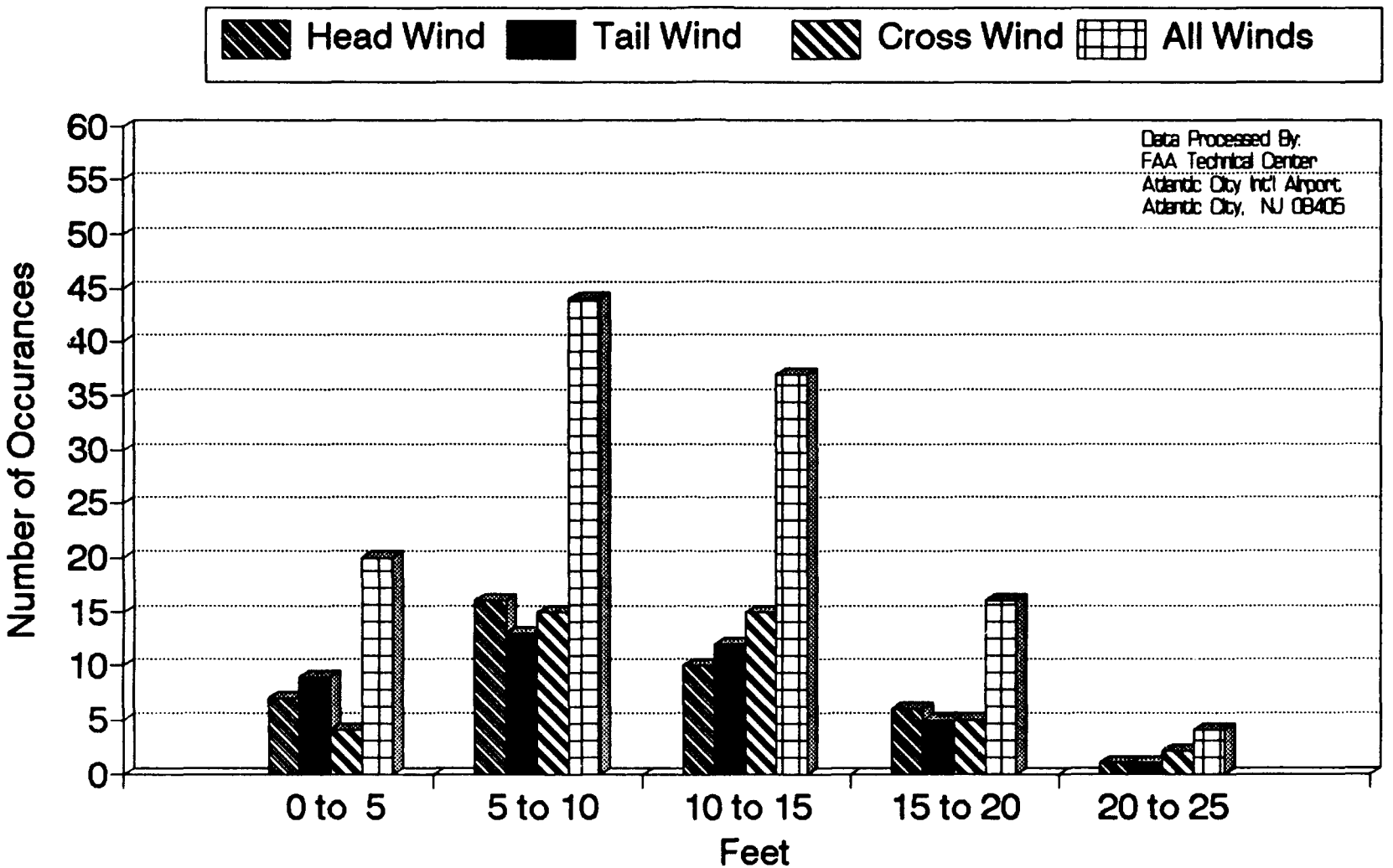

FIGURE 3. NUMBER OF OCCURRENCES FOR PILOT CHOICE ACTUAL CLEARANCES

(SHEET 1 OF 2)

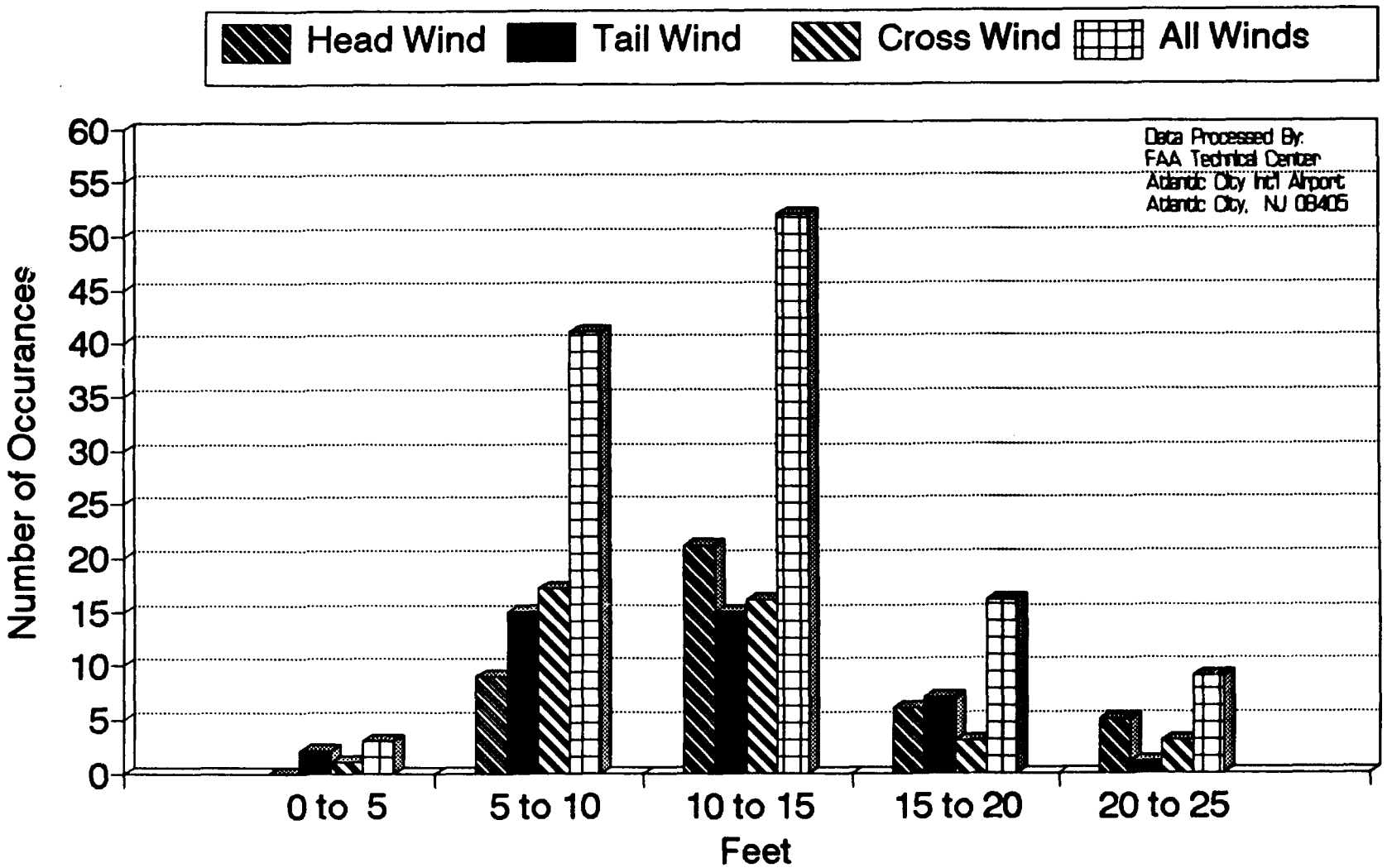

FIGURE 3. NUMBER OF OCCURRENCES FOR PILOT CHOICE ACTUAL CLEARANCES
(SHEET 2 OF 2)

Through further analysis of the means found in table 4, it was found that the difference was significant, that is, it was not due to chance. That indicates the pilots tended to park significantly closer to the ground marking than they did to the obstacle. Additional analysis of the means found in table 5 revealed that the difference between the mean clearance for headwind with an obstacle and for headwind without the obstacle was significant at the 95 and 99 percent confidence levels. That is, these differences would occur by chance less than one percent of the time. In addition, it was found that the difference between the mean for tailwind with obstacle and tailwind without obstacle is significant at the 95 percent level but not at the 99 percent level. That is, the difference would occur by chance less than five percent, but more than 1 percent of the time. These findings support the previous one that pilots tended to park closer to the ground marking than to the obstacle.

In order to determine how well pilots were able to estimate their rotor tip clearances, analysis of their errors in perception were computed by subtracting their estimated or perceived clearances from the actual clearances. Perception errors ranged from an underestimate of 5.45 ft to an overestimate of 17.09 ft from the obstacle and an underestimate of 4.55 ft to an overestimate of 13.64 from the ground marking. Table 6 contains the minimum and maximum errors by wind conditions. Table 7 contains the means and standard deviations of these perception errors. Plots of actual versus estimated tip clearances are found in figure 4. Points on the diagonal line represent the pilot's perception exactly matching the actual clearance achieved. Thus, points above the line represent actual clearances greater than what was perceived and those below represent actual clearances less than what was perceived. This is a quick way to determine whether the pilots' perceived clearance was larger or smaller than the actual clearance.

The plots in figure 5 present the number of occurrences for these perception errors.

TABLE 6. MINIMUM AND MAXIMUM PERCEPTION ERRORS
(Actual Clearance - Pilot Estimated Clearance)

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Minimum	-3.55	-4.55	-4.35
Maximum	12.02	13.64	12.45
N	40	41	40
With Obstacle			
Minimum	-3.14	-5.45	-5.40
Maximum	17.09	15.07	16.26
N	41	40	40

(The clearance criteria for an R-22 is 10 ft)

TABLE 7. PERCEPTION ERRORS

(Actual Clearance - Pilot Estimated Clearance)

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	2.49	2.78	1.90
SD	4.16	4.24	4.22
N	40	41	40
With Obstacle			
Mean	4.18	2.70	3.24
SD	4.60	4.47	4.98
N	41	40	40

Examination of the perception errors, regardless of wind type, revealed that with the object, 30 of the 121 perceived clearances were overestimated. That is, the pilot perceived his clearance as greater than his actual clearance. However, only six of these were overestimated by more than 3 ft. Similarly, 39 of the 121 perceived clearances were over estimated for the procedures with the ground marking. Of those, only six were by more than 3 ft.

These errors were also examined by winds. Clearances from the ground marking with tailwinds were overestimated the largest portion of the time. The clearances from the obstacle were overestimated the same portion of the time for the tailwind and crosswind procedures. However, it should be emphasized that at no time during these maneuvers did the rotor tip overlap either the obstacle or the ground marking.

No relationship was found between the actual distances and the pilots' helicopter experience nor between the perception errors and their experience.

REQUESTED 10-FT CLEARANCE.

During this portion of the test, the pilots were requested to park the helicopter with a 10-ft rotor tip clearance from either the ground marking or the obstacle.

Means of the actual tip clearances achieved under this restriction regardless of wind conditions are found in table 8, and by winds in table 9.

Further statistical analysis conducted on the means from both table 8 and 9 found a significant difference between the means found in table 8 only. However, the difference was significant at a 95 percent confidence level but not at the 99 percent confidence level. This again emphasizes the pilot's tendency to park closer to the ground marking than the obstacle.

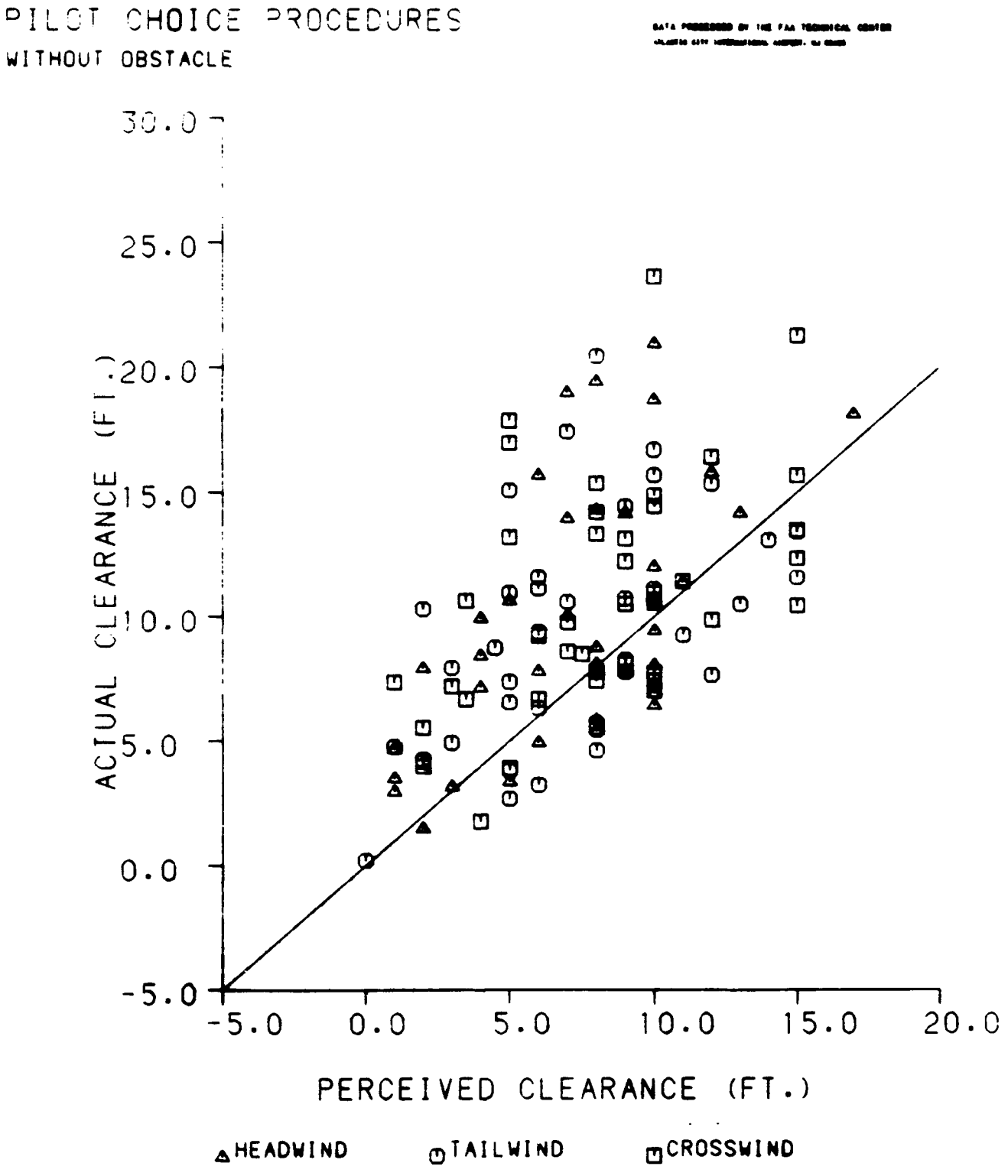

FIGURE 4. ACTUAL VS. PERCEIVED CLEARANCES BY WINDS

(SHEET 1 OF 2)

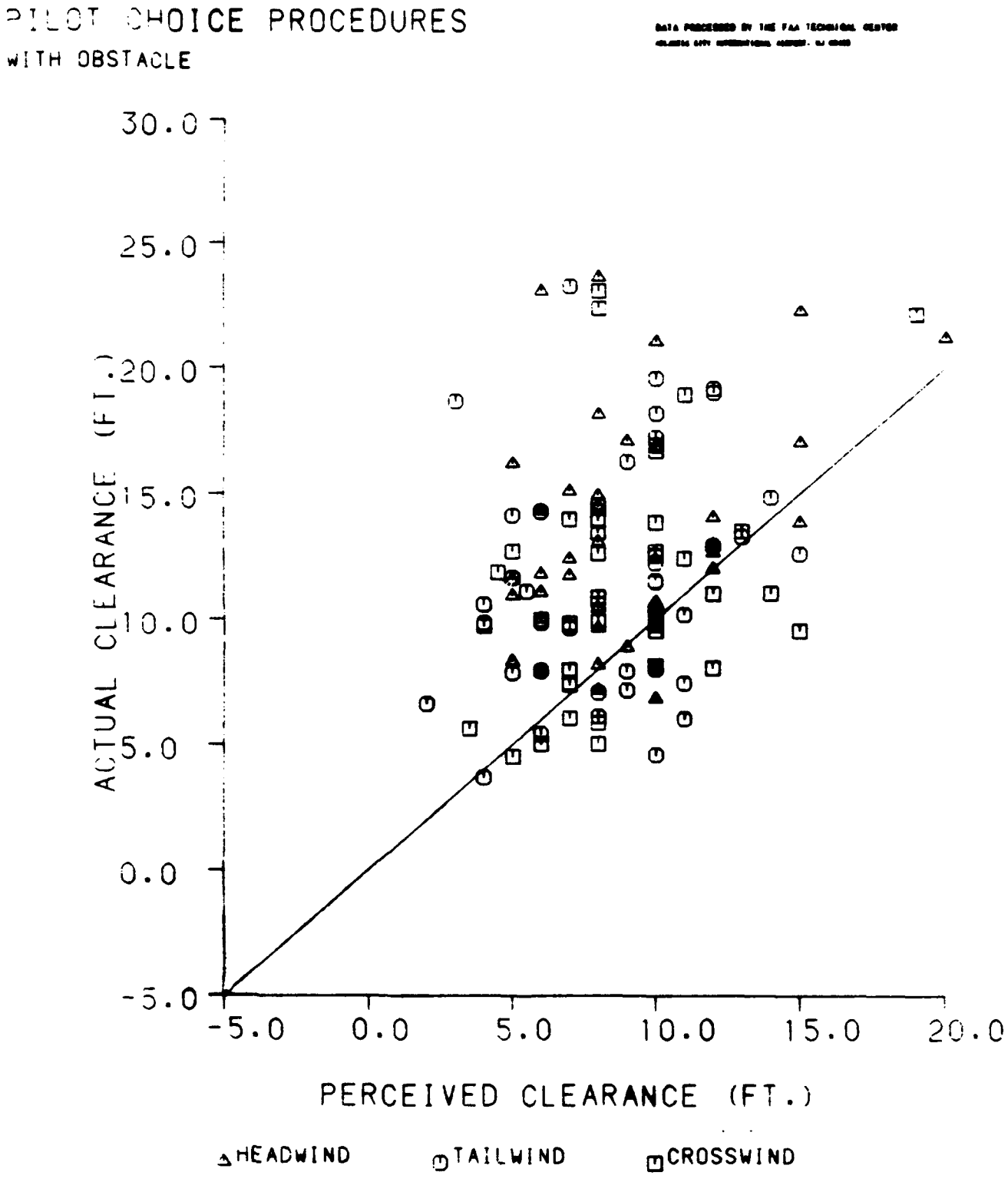

FIGURE 4. ACTUAL VS. PERCEIVED CLEARANCES BY WINDS

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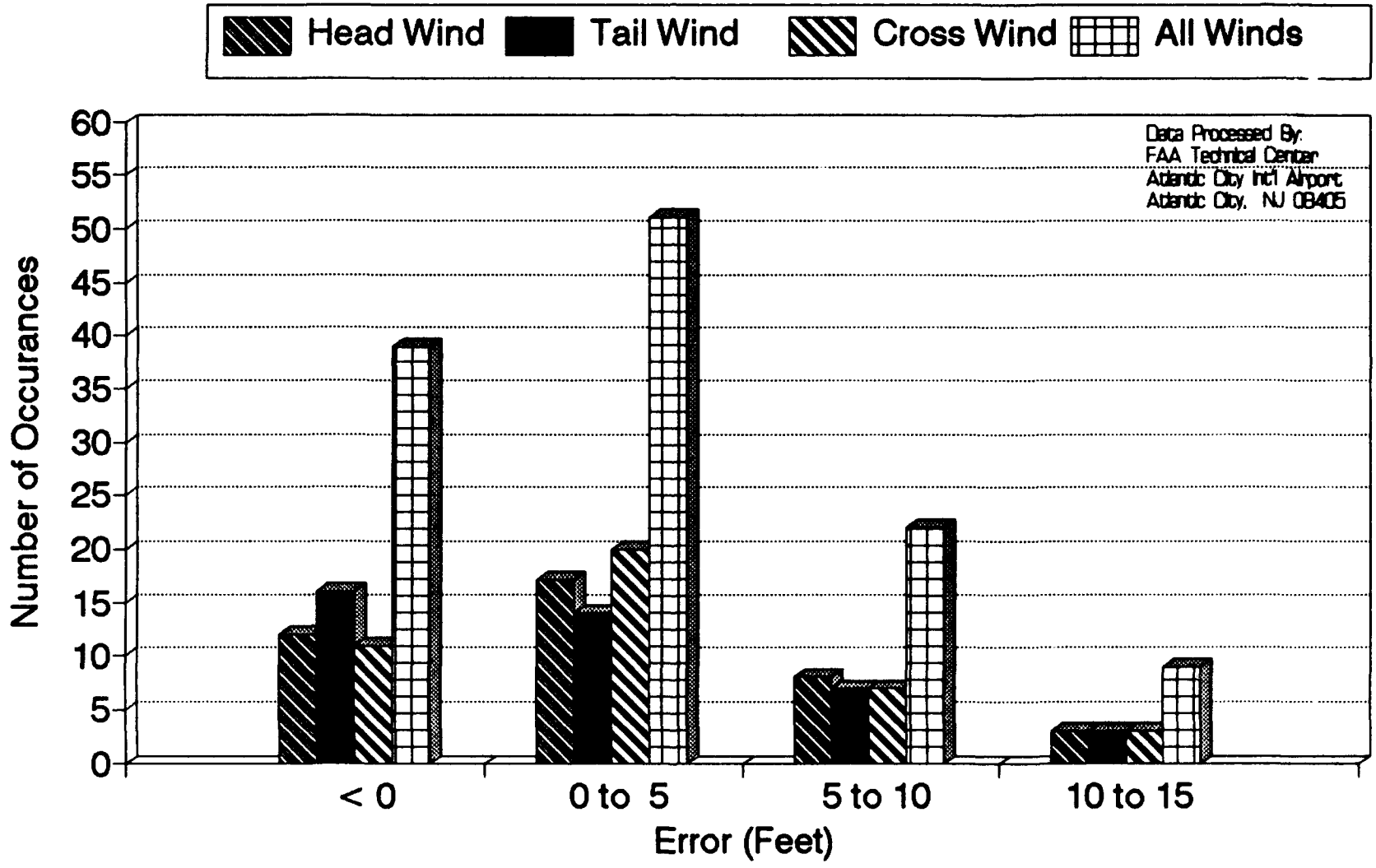

FIGURE 5. NUMBER OF OCCURRENCES FOR PILOT PERCEPTION ERRORS
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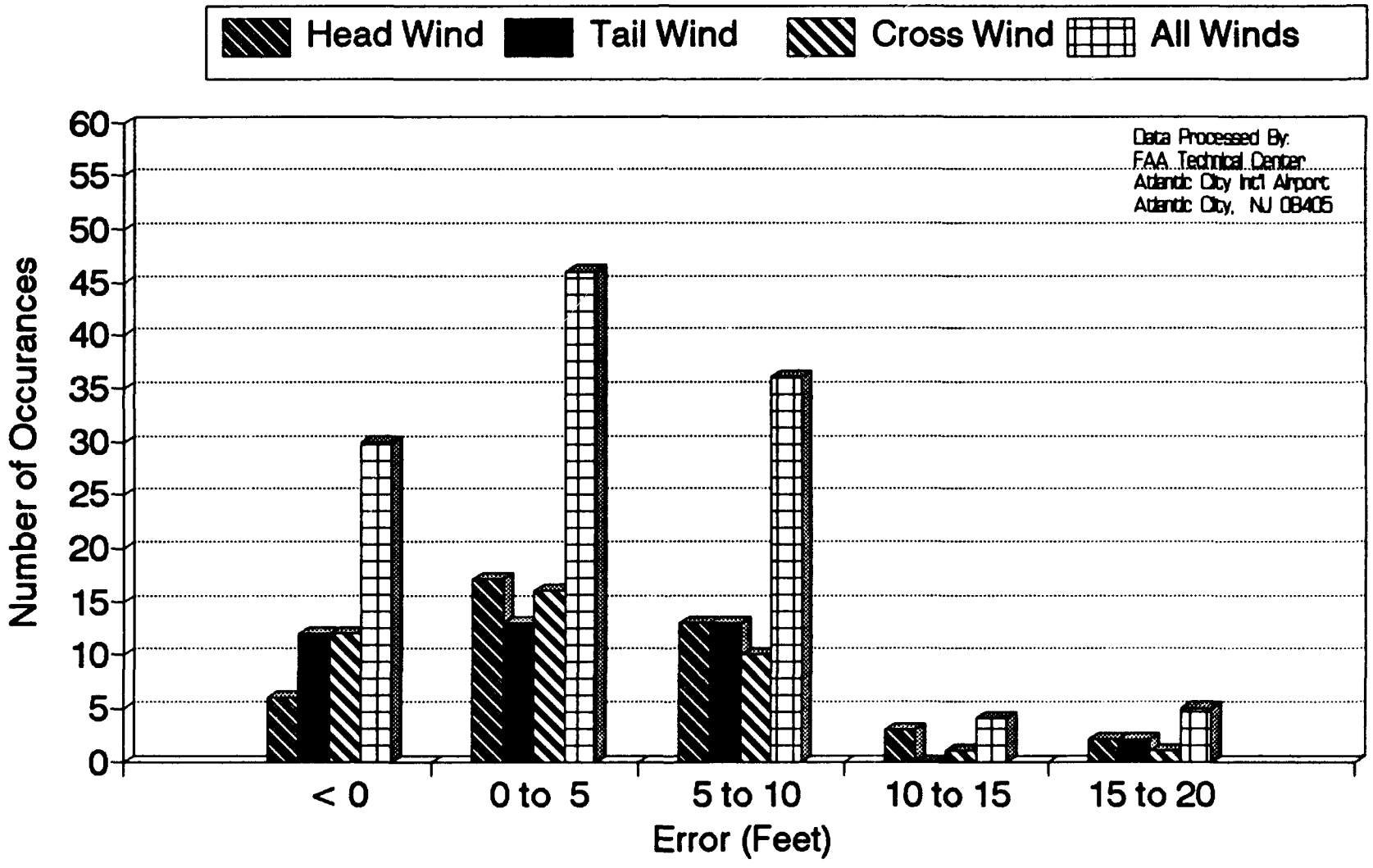


FIGURE 5. NUMBER OF OCCURRENCES FOR PILOT PERCEPTION ERRORS
(SHEET 2 OF 2)

TABLE 8. ACTUAL ROTOR TIP CLEARANCES REGARDLESS OF WIND TYPE WHEN ATTEMPTING 10-FT CLEARANCE

	In Feet	
	Without Obstacle	With Obstacle
Mean	13.96	15.13
SD	4.81	4.89
N	120	120

(The clearance criteria for an R-22 is 10 ft)

TABLE 9. ACTUAL ROTOR TIP CLEARANCES BY WINDS WHEN ATTEMPTING 10-FT CLEARANCES

	In Feet		
	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	13.78	14.76	13.34
SD	4.68	4.78	4.98
N	40	40	40
With Obstacle			
Mean	15.62	14.88	14.88
SD	5.09	4.92	4.75
N	40	40	40

(The clearance criteria for an R-22 is 10 ft)

When directed to park with a 10-ft tip clearance from the obstacle and from the ground marking, the pilots' actual tip clearances varied from 2.88 to 25.01 ft with only the ground marking for reference and from 3.90 to 25.94 ft with the obstacle. The actual ranges for each wind condition can be found in table 10.

Plots were also produced comparing the actual clearances to the requested 10-ft clearance. These plots are found in figure 6. The pilots parked their helicopter, regardless of wind conditions, closer than the 10-ft requested clearance 22 percent or 26 of the 120 times with only a ground marking as a reference, and 19 percent or 23 of the 120 times with the obstacle in place.

This tendency to park closer than requested from both the ground marking and the obstacle was much smaller than that seen during the daytime parking tests using the UH-1H (48 percent and 41 percent respectively). See appendix E for other comparisons.

TABLE 10. MINIMUM/MAXIMUM TIP CLEARANCES WHEN ATTEMPTING 10-FT CLEARANCE

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Minimum	2.88	5.79	3.20
Maximum	23.33	25.01	24.42
N	40	40	40
With Obstacle			
Minimum	6.09	4.43	3.90
Maximum	25.94	25.15	22.76
N	40	40	40

(The clearance criteria for an R-22 is 10 ft)

Performance errors were generated by subtracting the 10-ft requested clearance from the actual clearance. Performance errors ranged from 5.57 ft less than, to 15.94 ft greater than, the 10-ft requested clearance with the obstacle and from 7.08 less than, to 15.01 ft greater than, the 10-ft requested clearance with only the ground marking. Table 11 contains the minimum and maximum values of these performance errors by winds. Table 12 contains the mean and standard deviations of these errors. Plots showing the number of occurrences for these errors are found in figure 7.

These plots confirm that the pilots tended to park closer than the requested 10 ft from the ground marking than from the obstacle. From figure 6, it can be seen that with the obstacle in place more of the actual clearances tended to cluster from 10 to 20 ft. Table 12 data show that the pilot performance was better with the obstacle than the ground marking for both the tail and headwind conditions. However, there were no significant differences found among the means for the three wind conditions. Again, no relationship was found between the pilots' performance and their helicopter experience.

COOPER-HARPER/POST-MANEUVER RATINGS.

The Cooper-Harper Rating Scale used for the post-maneuver questionnaire employs a one to ten scale where a one, two or three indicates the maneuver is acceptable for routine operations. Ratings of four, five or six indicate the pilot felt the maneuver would be acceptable only on rare occasions, e.g., flight control system failure or severe atmospheric conditions. These ratings indicate there were more deficiencies and that the safety margin was deteriorating.

Figure 8 presents the results of the Cooper-Harper ratings in graphic form for the control factor. As seen, the control margin was rated as unacceptable for routine operations in 40 of 482 responses (20 out of 241 with no obstacle and 20 out of 241 with the obstacle). Twenty-four of those 40 unacceptable responses were under the tailwind conditions with 2 of those tailwind ratings given as 6.

PILOT PERFORMANCE DATA

ACTUAL TIP PATH CLEARANCE
WITHOUT OBSTACLE. REQUIRED 10 FOOT CLEARANCE

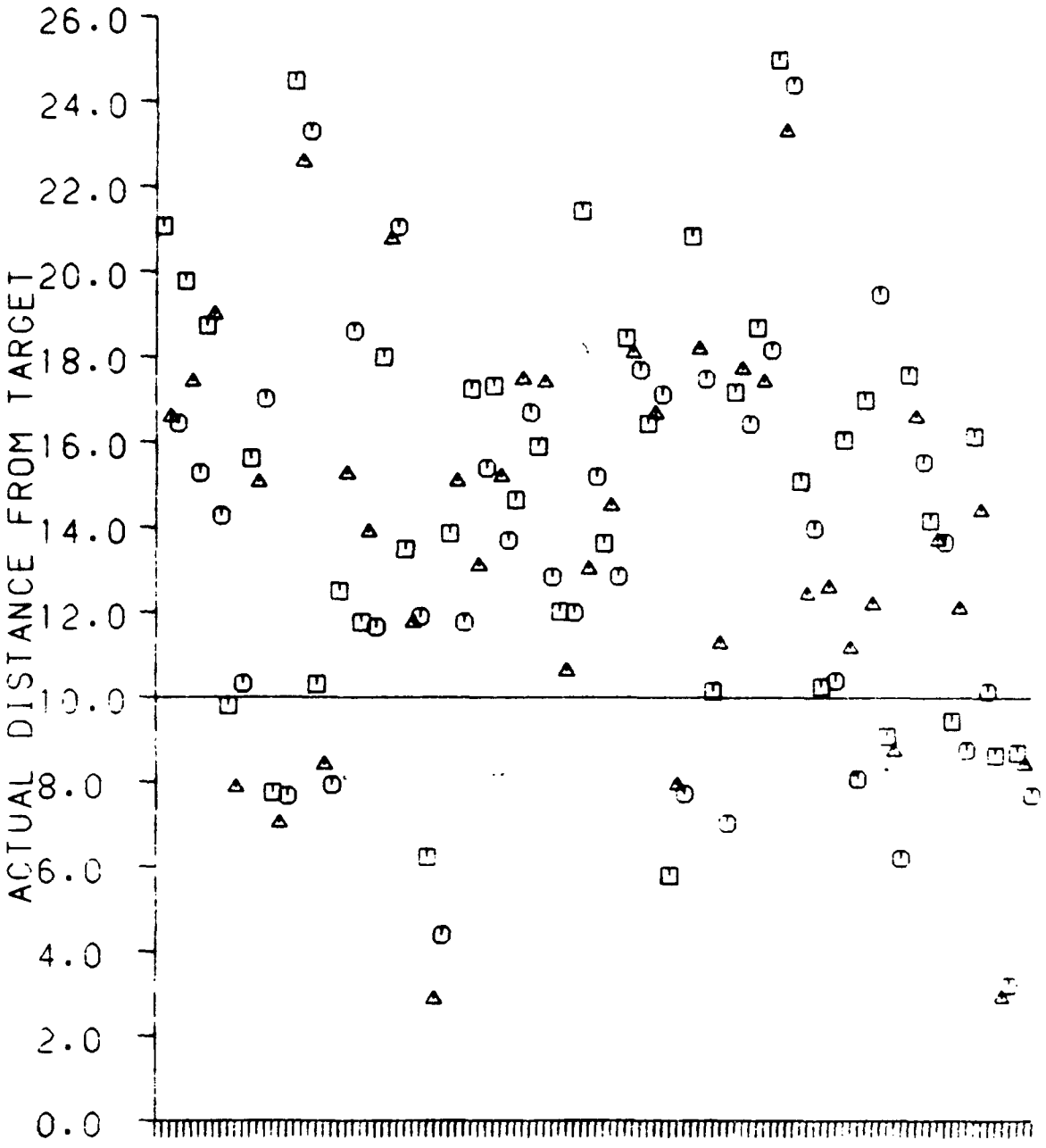


FIGURE 6. ACTUAL CLEARANCES WHEN ATTEMPTING 10-FT CLEARANCE

(SHEET 1 OF 2)

PILOT PERFORMANCE DATA

ACTUAL TIP PATH CLEARANCE
WITH OBSTACLE. REQUIRED 10 FOOT CLEARANCE

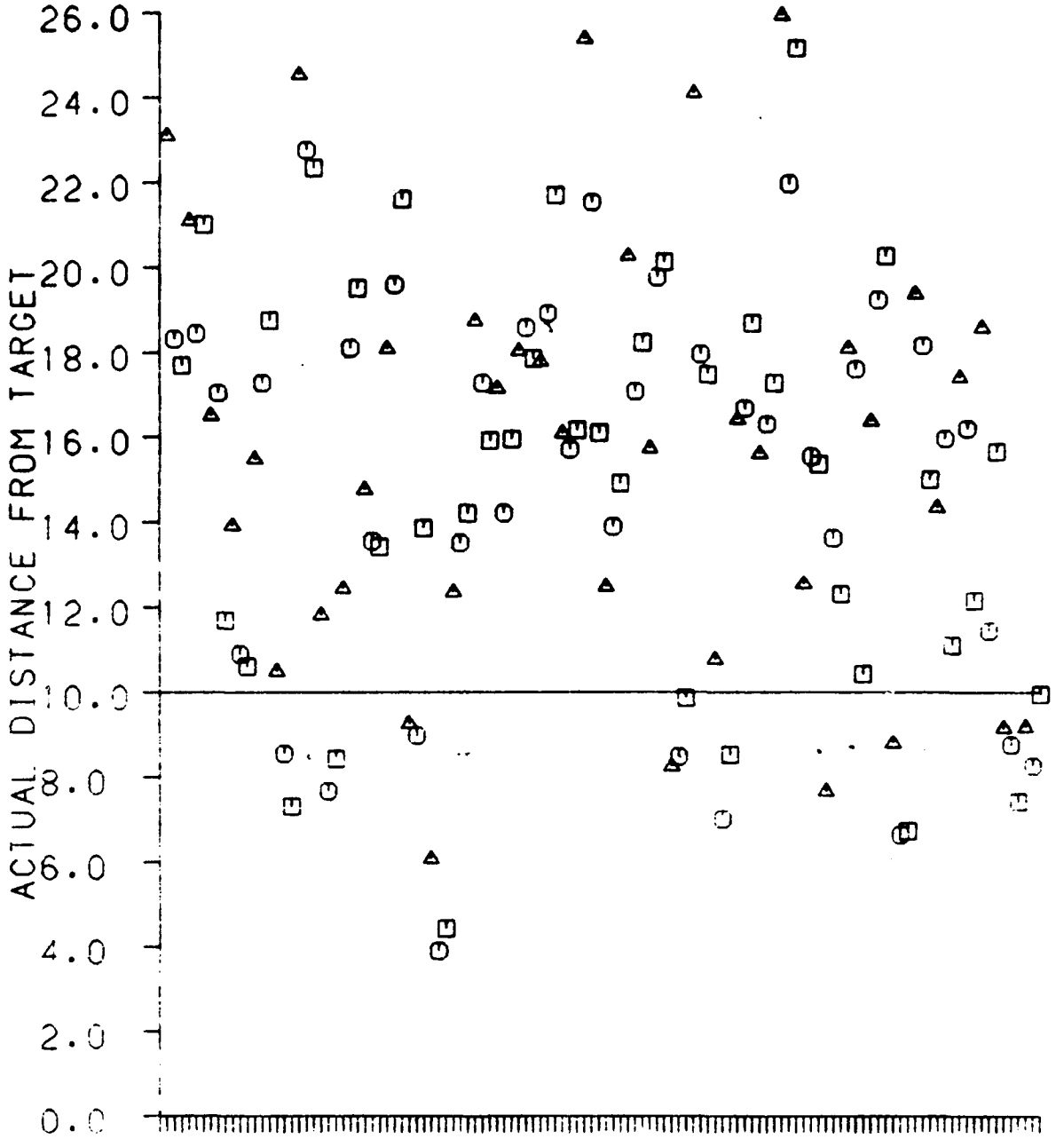


FIGURE 6. ACTUAL CLEARANCES WHEN ATTEMPTING 10-FT CLEARANCE

(SHEET 2 OF 2)

TABLE 11. MINIMUM AND MAXIMUM PERFORMANCE ERRORS

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Minimum	-7.08	-3.77	-6.80
Maximum	13.33	15.01	14.42
N	40	40	40
With Obstacle			
Minimum	-3.91	-5.57	-5.10
Maximum	15.94	15.15	12.76
N	40	40	40

(Actual Clearance - 10 ft)
(The clearance criteria for an R-22 is 10 ft)

TABLE 12. PERFORMANCE ERRORS

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	3.86	4.96	3.36
SD	4.61	4.87	4.99
N	40	40	40
With Obstacle			
Mean	5.47	4.88	4.93
SD	4.99	4.84	4.65
N	40	40	40

(Actual Clearance - 10 ft)

The plots for the safety margin responses are found in figure 9. Only 25 of the 482 responses fell into the unacceptable for routine operations category (10 of 241 without the obstacle and 15 of 241 with an obstacle). As with the control factor, the majority of unacceptable responses were given for the tailwind conditions.

The plots for the work load responses are found in figure 10. Of the 482 responses, 42 were unacceptable for routine operations (18 of 241 without the obstacle and 24 of 241 with the obstacle). Over half of those unacceptable ratings (25 of the 42) were with tailwind conditions, with 1 of those having a rating of 6.

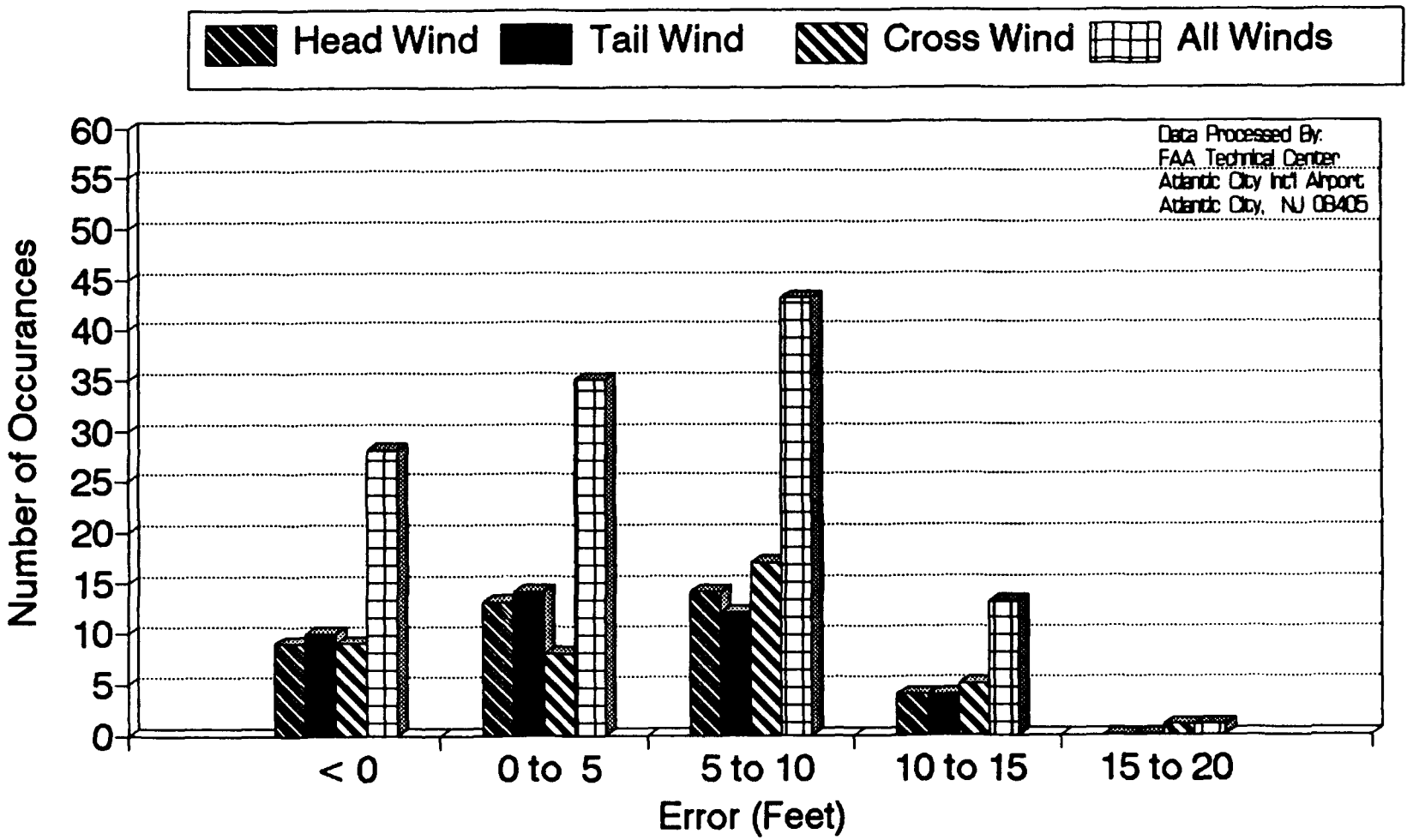


FIGURE 7. NUMBER OF OCCURRENCES FOR PERFORMANCE ERRORS
(SHEET 1 OF 2)

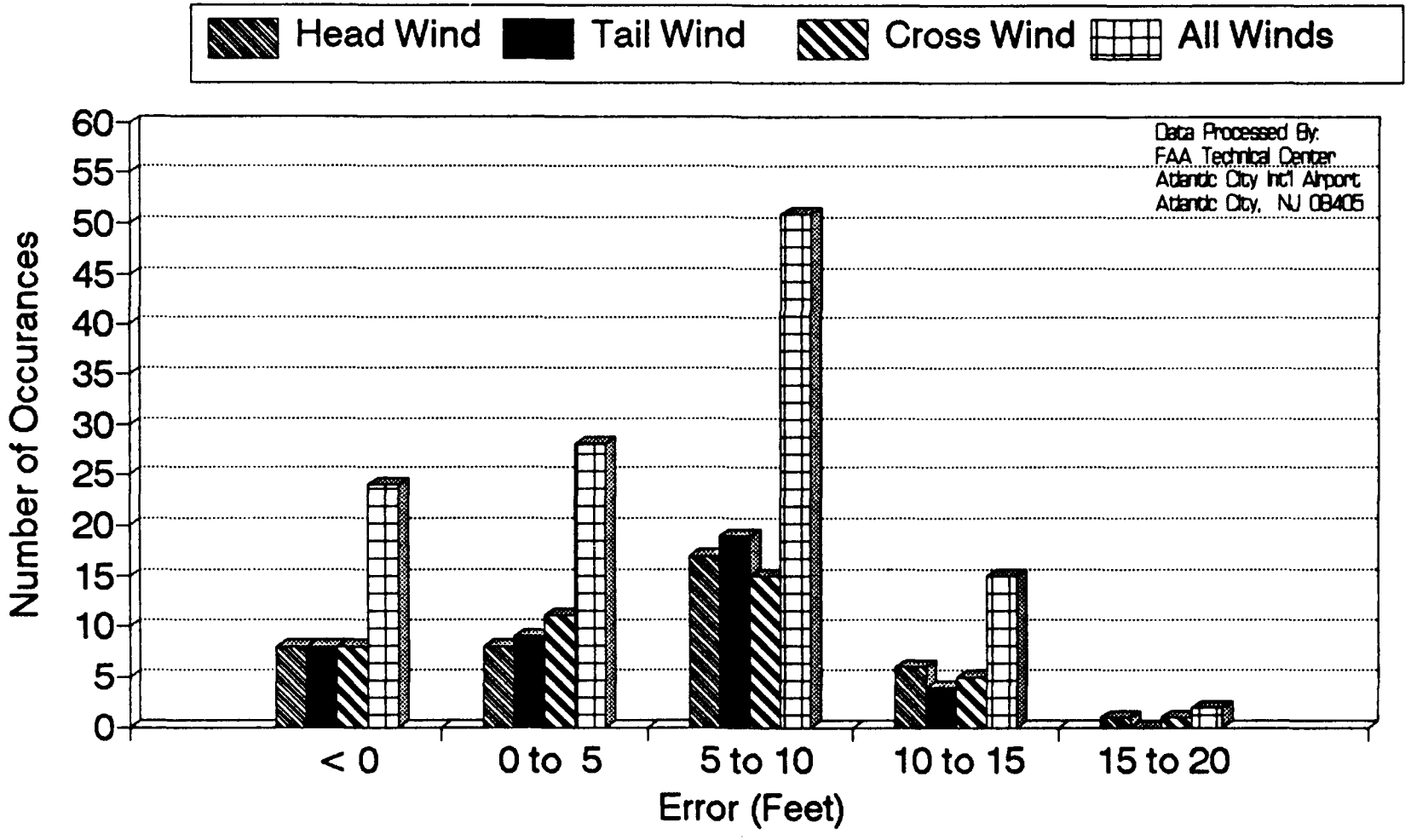


FIGURE 7. NUMBER OF OCCURRENCES FOR PERFORMANCE ERRORS

(SHEET 2 OF 2)

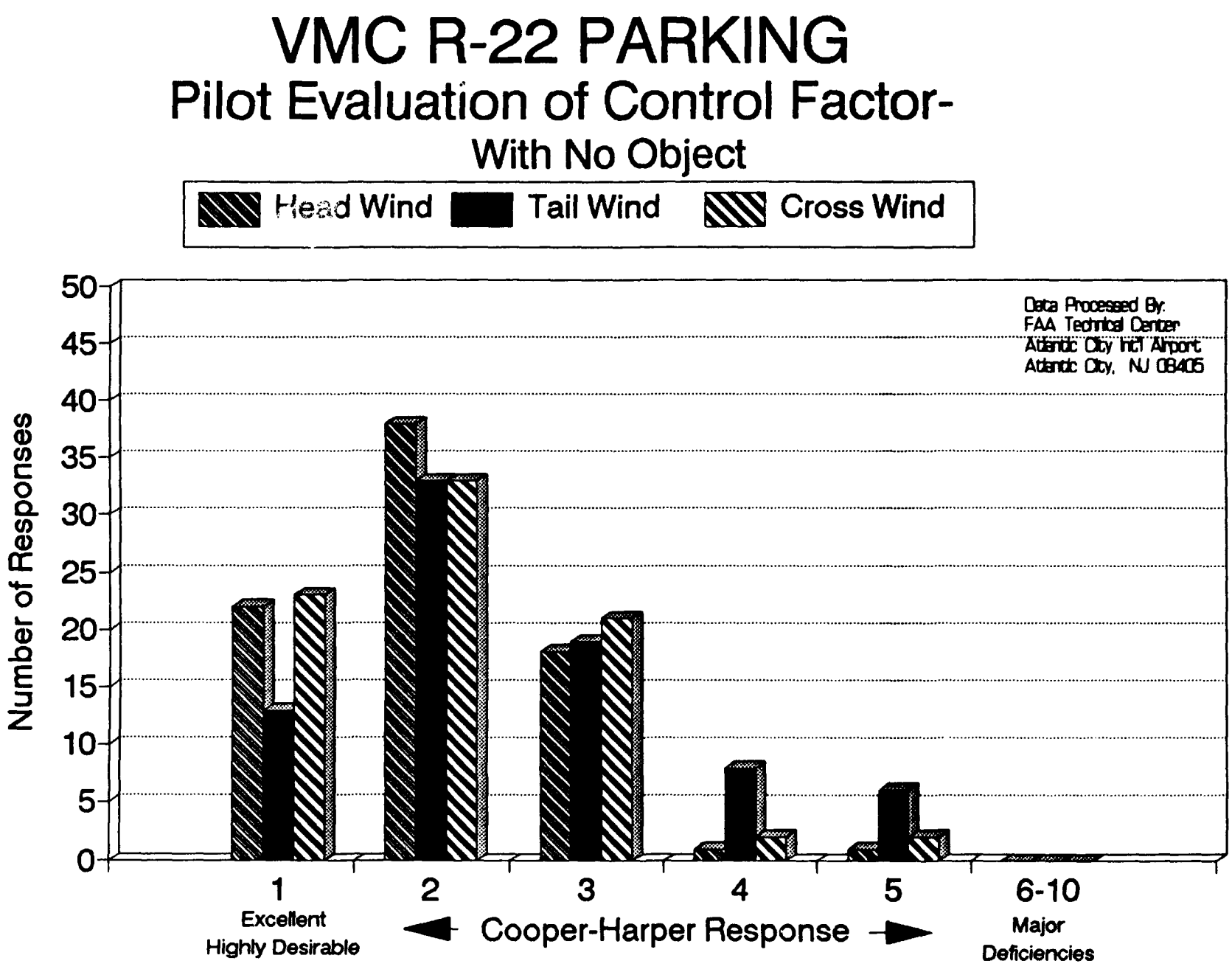


FIGURE 8. COOPER-HARPER RATINGS FOR CONTROL FACTOR
(SHEET 1 OF 2)

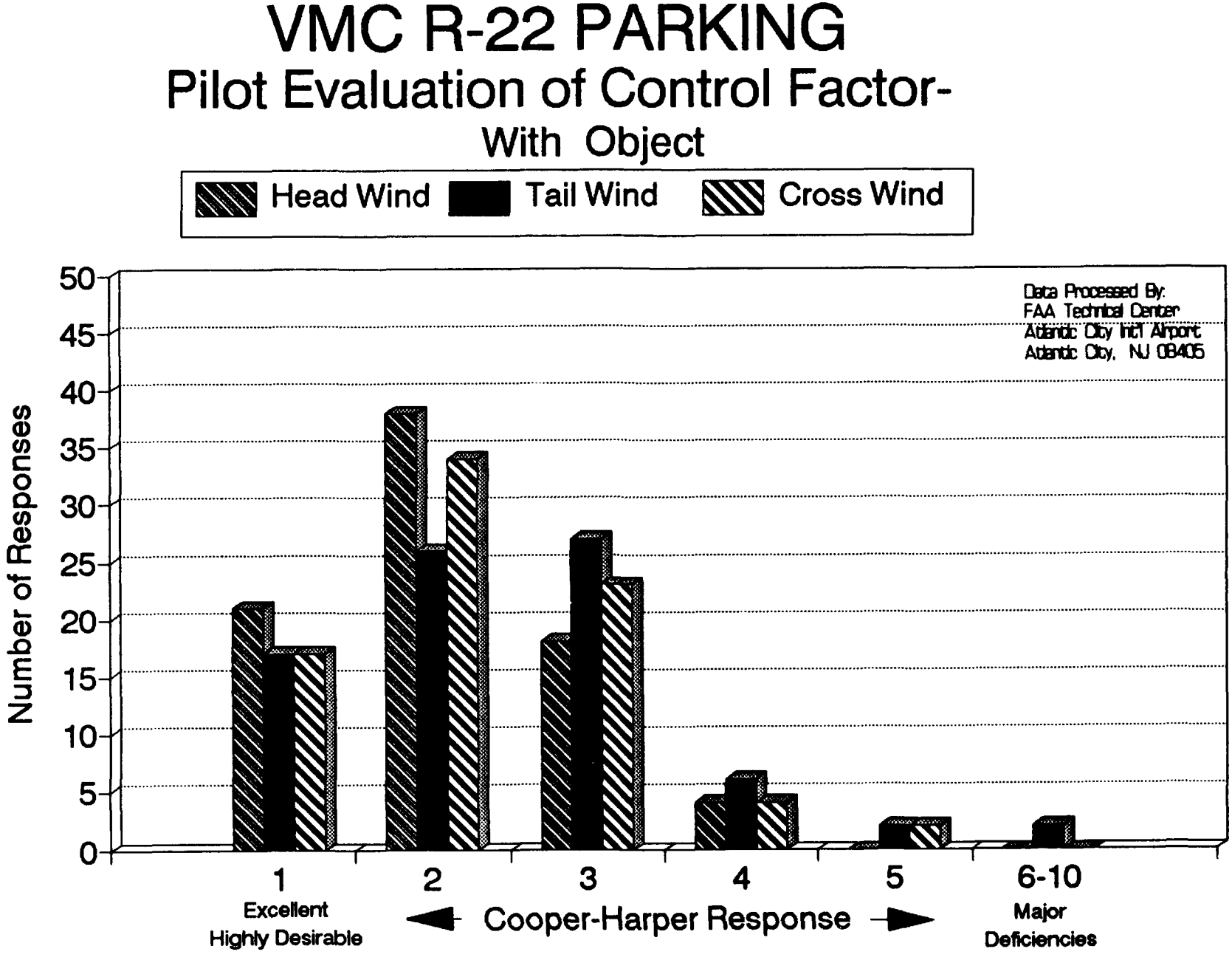


FIGURE 8. COOPER-HARPER RATINGS FOR CONTROL FACTOR
(SHEET 2 OF 2)

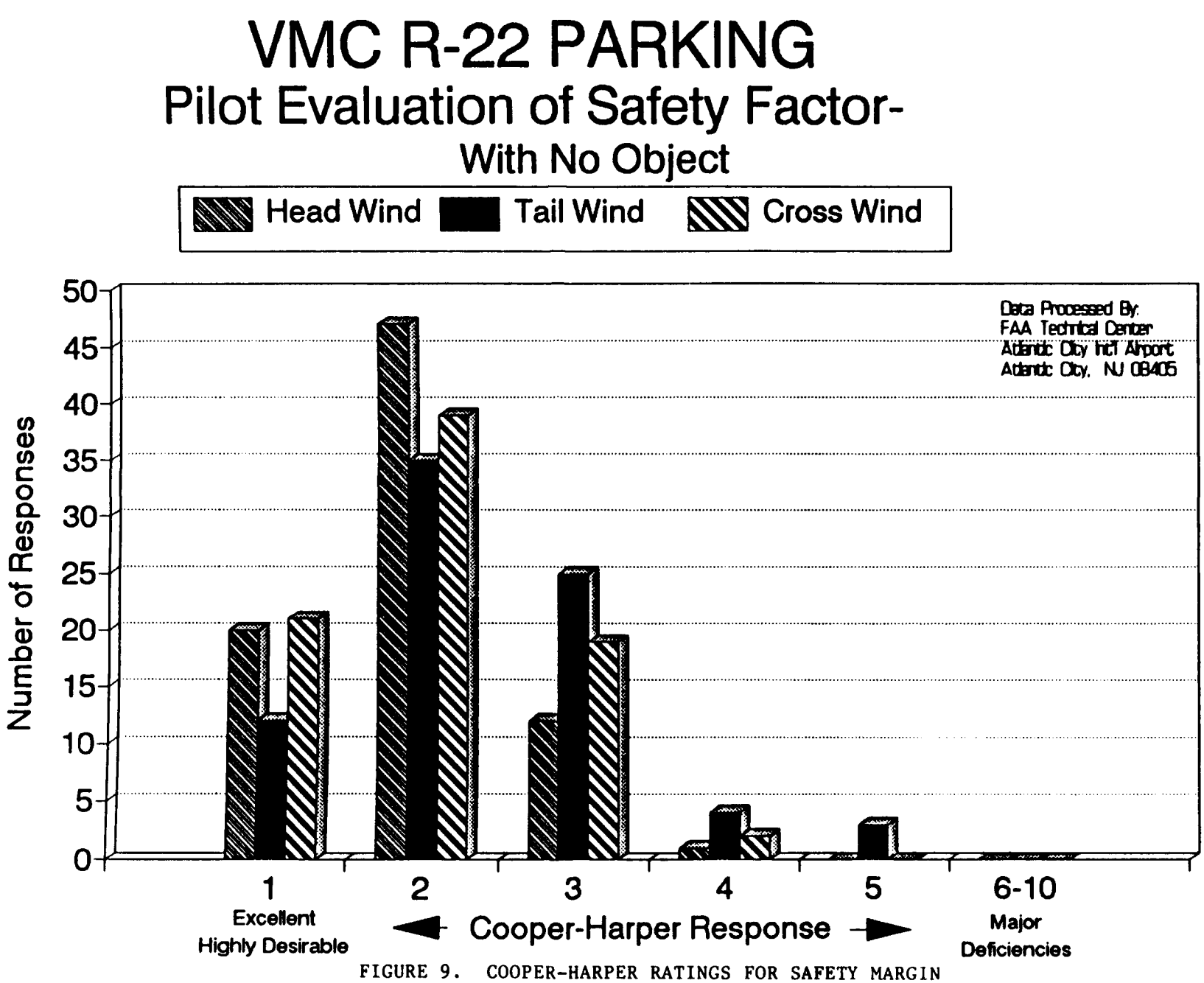


FIGURE 9. COOPER-HARPER RATINGS FOR SAFETY MARGIN
(SHEET 1 OF 2)

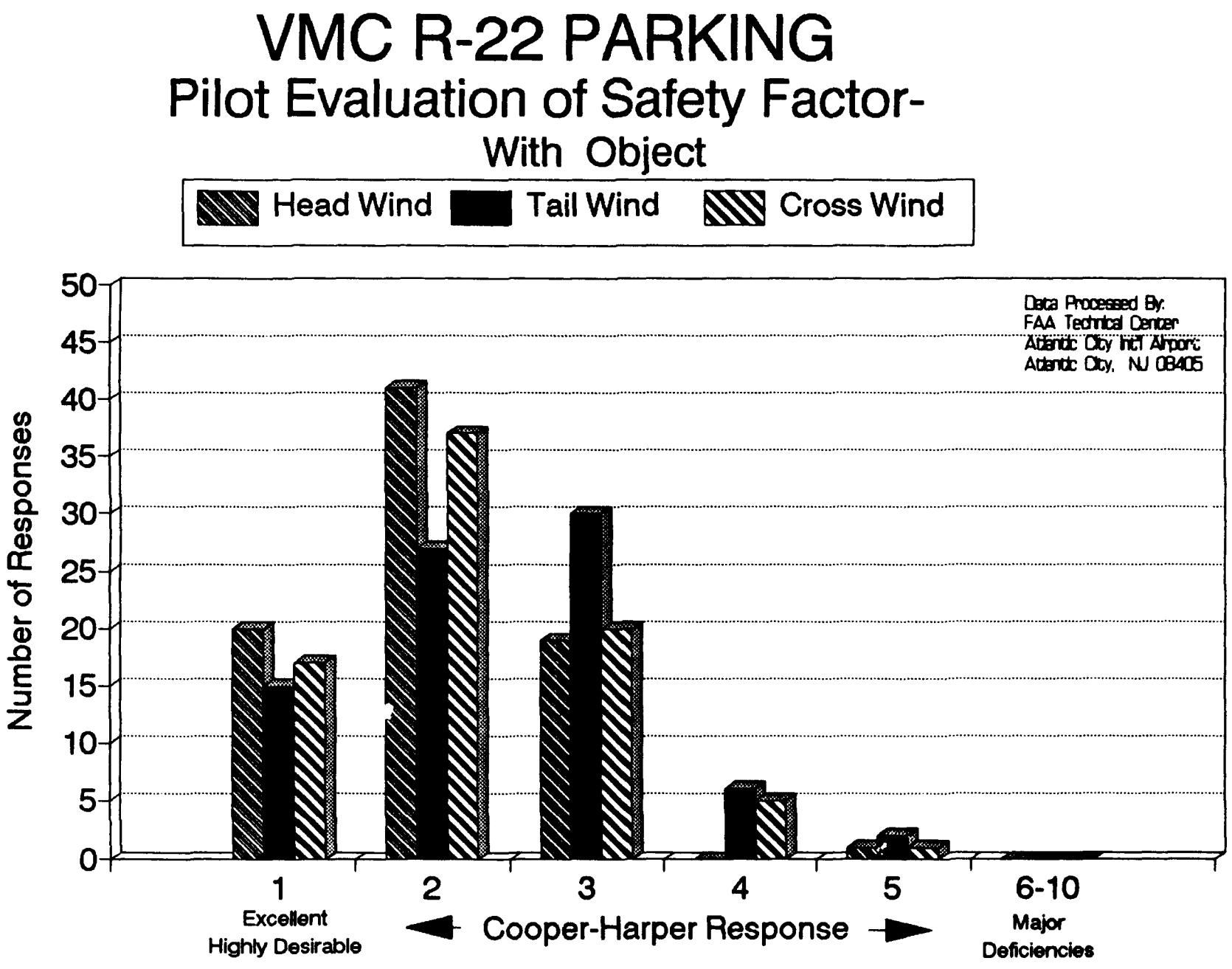


FIGURE 9. COOPER-HARPER RATINGS FOR SAFETY MARGIN
(SHEET 2 OF 2)

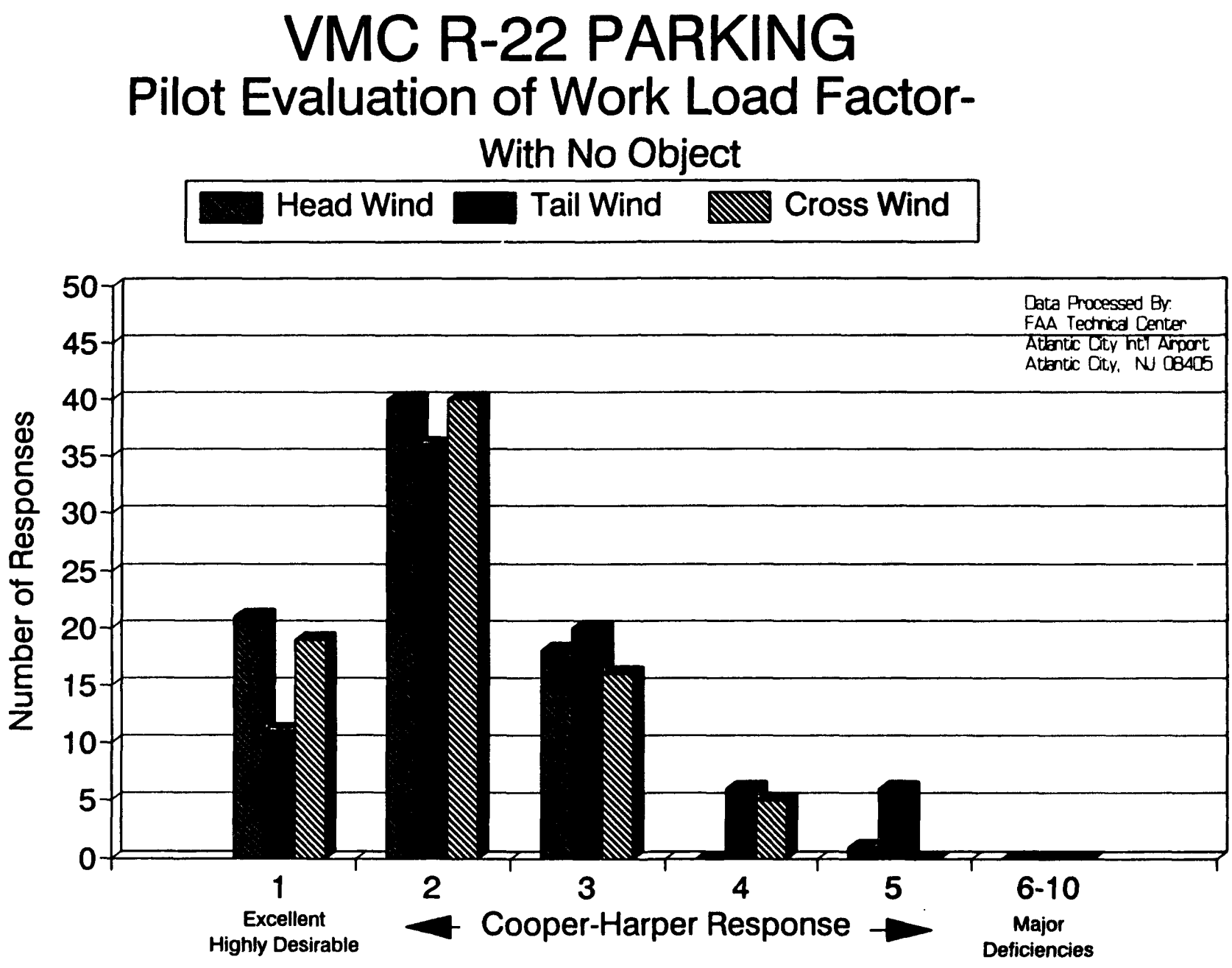


FIGURE 10. COOPER-HARPER RATINGS FOR WORKLOAD
(SHEET 1 OF 2)

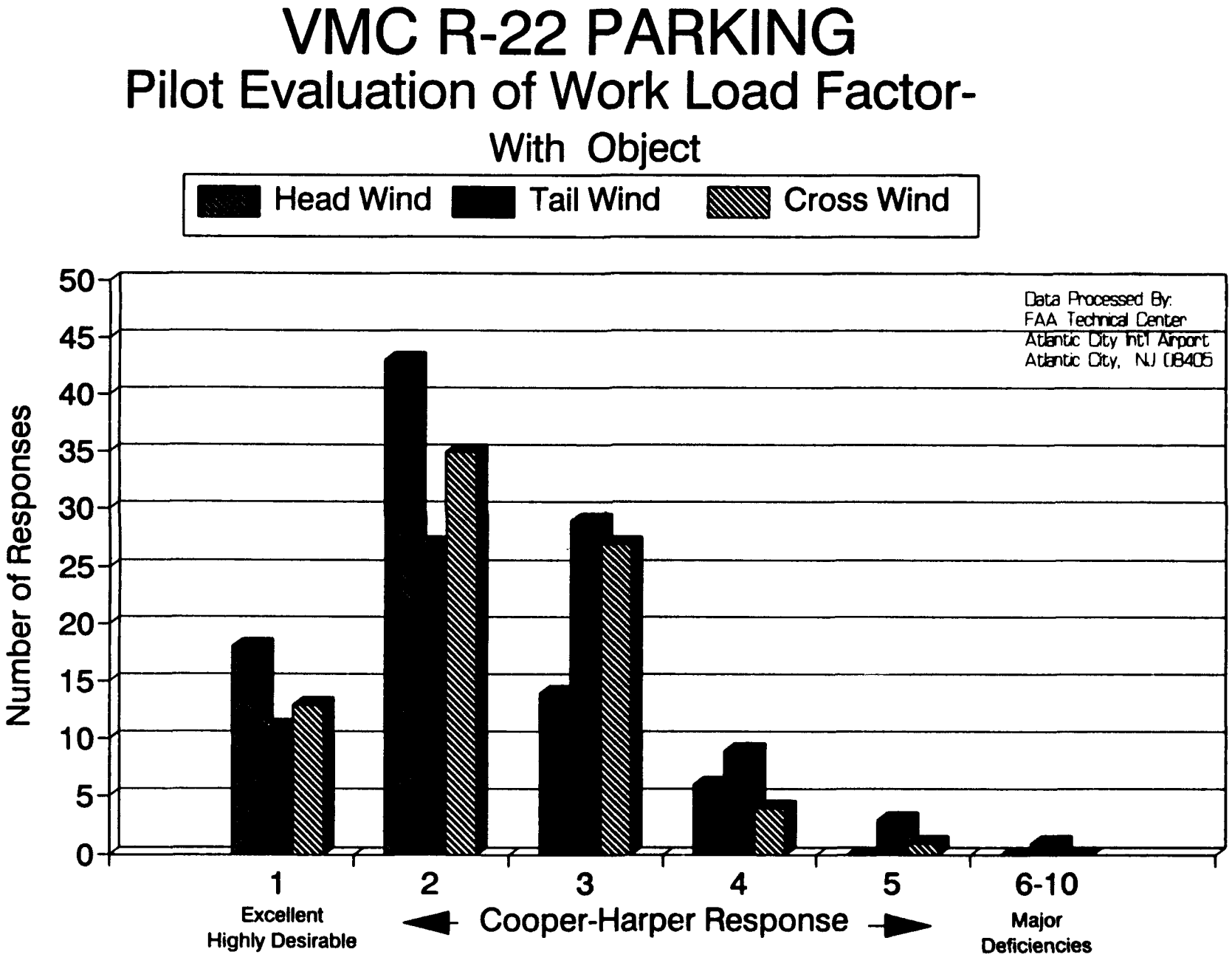


FIGURE 10. COOPER-HARPER RATINGS FOR WORKLOAD
(SHEET 2 OF 2)

Overall, however, even with those unacceptable ratings discussed above, the pilots tended to rate the procedures as acceptable.

POST-FLIGHT QUESTIONNAIRE.

Table 13 presents the responses to the post-flight questions. The first two questions employed a one to five scale where one is not comfortable, three is somewhat comfortable, and five is comfortable--no problem. The first question dealt with parking the aircraft 10 ft from the ground marking. For the crosswind conditions, out of 39 ratings, only 2 ratings were less than 3, with 6 ratings of 3. With the tailwind conditions, there were also only 2 ratings less than 3, with 12 ratings of 3. With the headwind conditions all the pilots gave ratings greater than three, that is, all felt comfortable with the procedure. Thus, they were less comfortable maneuvering the aircraft with tailwinds when they had to stay clear of the ground line. This corresponds to their in-flight ratings, which also indicated they were uncomfortable with the tailwind maneuvers.

The second question dealt with parking the aircraft 10 ft from the obstacle. For the crosswind conditions, out of 38 ratings, only 1 rating was less than 3, with 10 ratings of 3. With the tailwind conditions, there was also only 1 rating less than 3, with 15 ratings of 3. With the headwind conditions, all the pilots gave ratings greater than 3, that is, all felt comfortable with the procedure. Thus, as seen with the ratings for parking 10 ft from the line, the pilots were not very comfortable maneuvering the aircraft with tailwinds and with crosswinds.

When asked what they considered a *minimum safe rotor tip clearance* when parking in close proximity to an object with tail and crosswind conditions, the pilots tended to respond with 10 ft or more a larger portion of the time than they did for headwind conditions.

This corresponds to their ratings for questions one and two which also indicates that tail and cross wind conditions present more of a challenge and require more skill and concentration.

Further proof of this is seen in question four, where all those who felt they were influenced by the winds chose tail and cross winds as the influencing factor.

CONCLUSIONS

1. When given the option of determining their own safe rotor tip clearance, the maximum mean clearance of 13.21 corresponds closely with the current design guide criteria of 1/3 rotor diameter, but not less than 10 feet (ft). This maximum mean value occurred under headwind conditions with the obstacle in place. The actual clearances tended to cluster between 5 and 18 ft.

2. When asked to park parallel to the obstacle with a 10-ft clearance, the maximum mean clearance was approximately 6 ft greater than the requested 10-ft clearance. With only the ground mark, the maximum mean clearance was approximately 5 ft greater than the requested 10 ft. This 10-ft clearance is contained in the current design guide.

TABLE 13. RESPONSES TO POST FLIGHT QUESTIONS

1. How comfortable did you feel parking 10 feet from the ground mark with:

	1	2	3	4	5
Headwind				8	32
Tailwind	1	1	12	10	16
Crosswind	1	1	6	18	14

2. How comfortable did you feel parking 10 feet from the obstacle with:

	1	2	3	4	5
Headwind			1	11	27
Tailwind		1	15	9	14
Crosswind	1		10	16	12

3. When parking in close proximity to an object what do you consider the minimum safe rotor tip clearance (in feet) with:

	<=9	10	11	12	13	14	15	16	>16
Headwind	10	20		5			1		4
Tailwind	5	14		2	3	1	11		4
Crosswind	4	14		3	2		11	1	5

4. .... which condition had the greatest impact on your performance?

Headwind.... 0
Tailwind.... 14
Crosswind... 20

Both tailwind and crosswind... 1
None of the 3 4

Note: For questions one and two, a one indicates the pilot was not comfortable with the maneuver, while five indicates the pilot was comfortable with it.

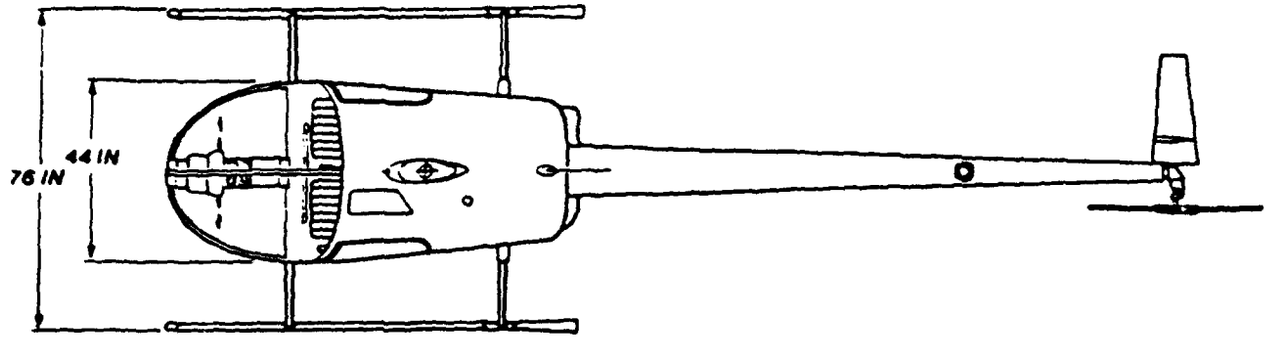
The actual clearances, when asked to park 10 ft from either the ground mark or the obstacle, clustered between 10 and 20 ft. This indicates that the pilots tend to perform on the safe side. In general, the pilots tended to park slightly further from the obstacle than from the ground mark.

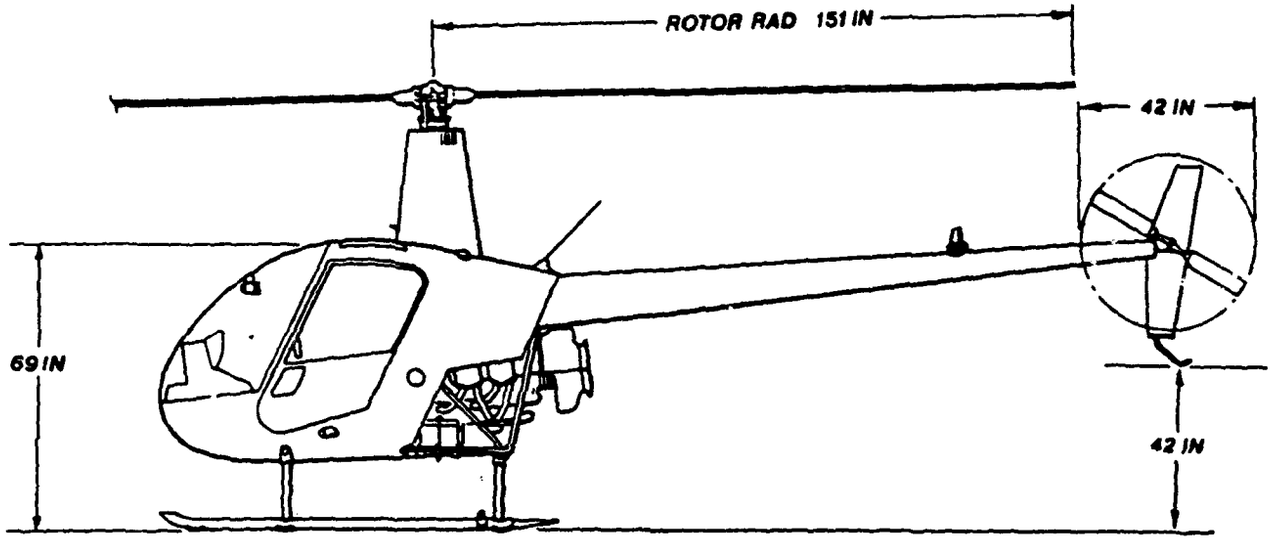
3. The mean perception and performance errors support the conclusion that the pilots tended to perform on the safe side. That is, their actual distances tended to be further than either of their estimates when they determined their own clearances or the 10-ft requested clearances. It is important to again note that there were no occasions where the rotor tip overlapped either the obstacle or the ground marking.

4. Although the means and standard deviations for the actual clearances for both the pilot choice and 10-ft requested procedures do not indicate a significant difference in performance with tailwind conditions, the Cooper-Harper ratings and the post-flight questionnaire ratings show that the pilots are less comfortable with parking the R-22 with a tailwind. Given that the R-22 is a small, light, close-coupled control aircraft, there is a need to thoroughly account for the wind conditions when developing space limits for parking at any particular heliport.

5. No relationship was found between the actual distances and the pilots' helicopter experience nor between the perception errors and their experience.

APPENDIX A
R-22 SPECIFICATIONS

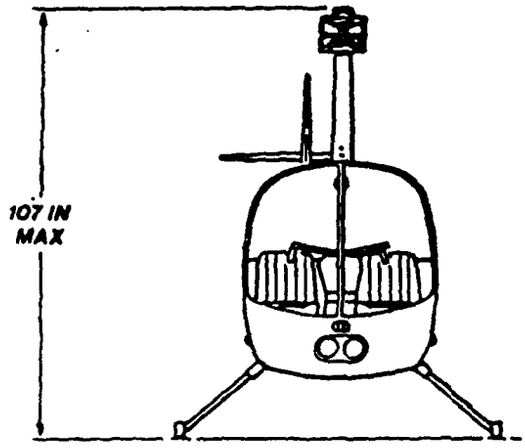


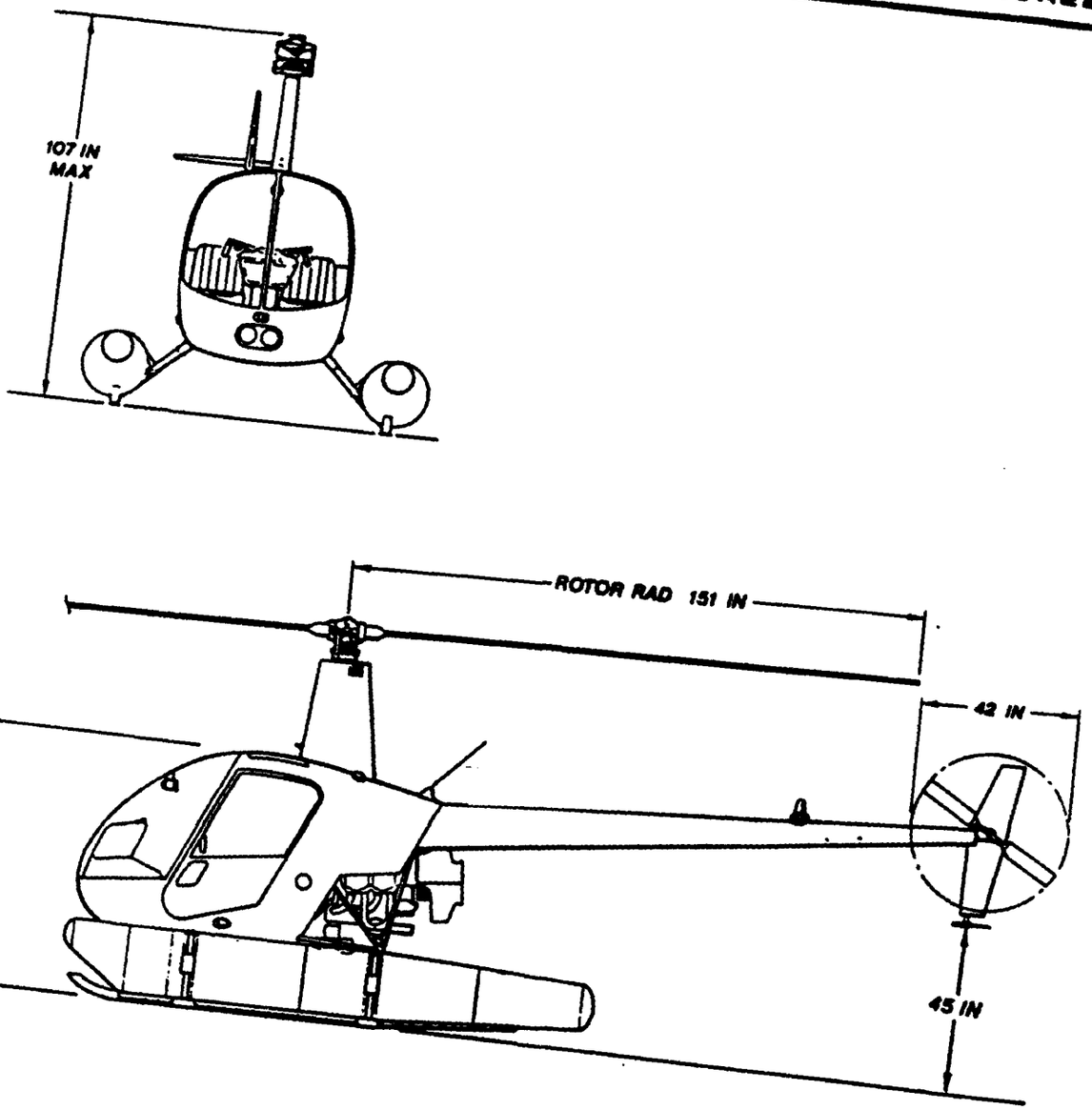


1.006 External Dimensions (cont'd)

R22 Alpha & Beta

EXTERNAL DIMENSIONS





1.006 External Dimensions

R22 Mariner

EXTERNAL DIMENSIONS

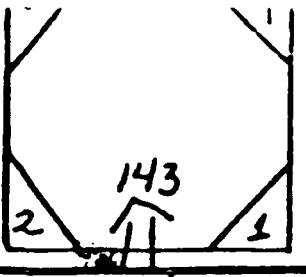
APPENDIX B
ONBOARD LOG

R22 DAY TIME PARKING

DATE: _____ FLIGHT #: DR22_____.LOG

SUBJECT PILOT: _____

SAFETY PILOT: PAUL DEMKO



RUN	TYPE OBJ/WIND	WINDS	SPOT #	SAFE/GIVEN DIST.	EST. DIST.	ACTUAL DIST.	SPOT M-DIST		RATINGS CTL	SFE	DMD
1	OBJ/HW										
2	NOOBJ/CW										
3	OBJ/TW										
4	NOOBJ/HW										
5	OBJ/CW										
6	NOOBJ/TW										
7	OBJ/HW			10							
8	NOOBJ/CW			10							
9	OBJ/TW			10							
10	NOOBJ/HW			10							
11	OBJ/CW			10							
12	NOOBJ/TW			10							

WOULD YOU CONTINUOUSLY PERFORM THIS MANEUVER UNDER THESE CONDITIONS IN TERMS OF:

CONTROLLABILITY (CTL); SAFETY (SFE); DEMANDS ON THE PILOT (DMD);

COMMENTS:

APPENDIX C
POST-FLIGHT QUESTIONNAIRE

VISUAL METEOROLOGICAL CONDITIONS (VMC)

DAY TIME PARKING: POST TEST QUESTIONNAIRE

Location: FAA Technical Center Aircraft: _____

Test Date: _____

OPERATIONAL PILOT INFORMATION:

NAME: _____

AFFILIATION: _____

ADDRESS: _____

CITY: _____ STATE: _____ ZIP: _____

PHONE (OPTIONAL): _____

FAA HELICOPTER RATINGS: _____

_____

TOTAL FLIGHT HOURS: _____

TOTAL HELICOPTER HOURS: _____

TOTAL TIME IN TYPE: _____

TOTAL HELICOPTER HOURS LAST 6 MONTHS: _____

TIME IN TYPE LAST 6 MONTHS: _____

PROCEDURAL QUESTIONS

1. How comfortable did you feel parking 10 feet from the ground mark:

   a. With a headwind? 1 2 3 4 5

   Not Comfortable Somewhat No Problem- Ok

   b. With a tailwind? 1 2 3 4 5

   Not Comfortable Somewhat No Problem-OK

   c. With a crosswind? 1 2 3 4 5

   Not Comfortable Somewhat No problem- OK

2. How comfortable did you feel parking 10 feet from the obstacle:

   a. With a headwind? 1 2 3 4 5

   Not Comfortable Somewhat No problem- OK

   b. With a tailwind? 1 2 3 4 5

   Not Comfortable Somewhat No problem- OK

   c. With a crosswind? 1 2 3 4 5

   Not Comfortable Somewhat No problem- OK

3. When parking in close proximity to an object what do you consider the minimum safe rotor tip clearance: (in feet)

   a. with a headwind?

   b. with a tailwind?

   c. with a crosswind?

4. Do you feel wind conditions influence your parking performance significantly?

   If so, which condition had the greatest impact on your performance?

   a. Headwind conditions

   b. Tailwind conditions

   c. Crosswind conditions

5. How do you like the new symbol on the heliport?

COMMENTS:

APPENDIX D
ACTUAL TEST DATA

ACTUAL DATA FOR PILOT CHOICE MANEUVERS

Actual Winds	Light/Object Condition	Wind Type	Safe Dist.(ft)	Estimated Dist.(ft)	Actual Dist.(ft)	Act/Est Calculated Perception Errors(ft)
FLIGHT DATE: 9-9-91						
calm	object	HW	10	10	10.63	0.63
calm	no object	CW	9	9	8.10	-0.90
calm	object	TW	9	9	7.17	-1.83
calm	no object	HW	9	9	7.76	-1.24
calm	object	CW	10	10	10.22	0.22
calm	no object	TW	9	9	8.26	-0.74
FLIGHT DATE: 9-9-91						
calm	object	HW	6	6	11.83	5.83
calm	no object	CW	6	6	9.23	3.23
calm	object	TW	5	5	7.87	2.87
calm	no object	HW	4	4	8.44	4.44
calm	object	CW	6	6	9.98	3.98
calm	no object	TW	6	6	9.38	3.38
FLIGHT DATE: 9-10-91						
230/12	object	HW	8	8	7.2	-0.8
230/12	no object	CW	8	8	7.8	-0.2
230/12	object	TW	8	8	6.12	-1.88
260/11	no object	HW	8	8	5.87	-2.13
250/13	object	CW	8	8	5.86	-2.14
250/13	no object	TW	8	8	4.63	-3.37
FLIGHT DATE: 9-11-91						
299/3	object	HW	7	7	11.76	4.76
230/10	no object	CW	9	9	13.14	4.14
230/10	object	TW	10	10	18.18	8.18
320/8	no object	HW	8	8	14.31	6.31
320/8	object	CW	8	8	14.52	6.52
360/10	no object	TW	10	10	11.10	1.10
350/10	object	HW	9	9	17.10	8.10
350/10	no object	CW	8	8	14.20	6.20
FLIGHT DATE: 9-11-91						
360/5	object	HW	15	15	22.29	7.29
360/5	no object	CW	10	10	14.44	4.44
360/5	object	TW	12	12	19.15	7.15
360/7	no object	HW	17	17	18.17	1.17
360/7	object	CW	19	19	22.16	3.16
360/7	no object	TW	10	10	15.69	5.69

ACTUAL DATA FOR PILOT CHOICE MANEUVERS (continued)

FLIGHT DATE: 9-12-91

050/5	object	HW	8	8	23.64	15.64
050/5	no object	CW	5	5	16.98	11.98
050/5	object	TW	7	7	23.26	16.26
040/7	no object	HW	7	7	19.02	12.02
040/7	object	CW	8	8	22.37	14.37
020/7	no object	TW	7	7	17.43	10.43

FLIGHT DATE: 9-12-91

030/6	object	HW	15	15	17.06	2.06
030/6	no object	CW	15	15	13.48	-2.52
030/6	object	TW	7	7	9.65	2.65
040/5	no object	HW	6	6	7.82	1.82
040/5	object	CW	7	7	9.84	2.84
040/7	no object	TW	5	5	10.96	5.96

FLIGHT DATE: 9-16-92

280/10	object	HW	10	10	10.41	0.41
280/10	no object	CW	15	15	10.45	-4.55
280/10	object	TW	15	15	12.61	-2.39
280/10	no object	HW	10	10	6.92	-3.08
270/9	object	CW	15	15	9.55	-5.45
270/9	no object	TW	5	5	7.38	2.38

FLIGHT DATE: 9-16-91

260/8	object	HW	8	8	13.09	5.09
260/8	no object	CW	9	9	12.22	4.22
260/8	object	TW	10	10	12.25	2.25
270/8	no object	HW	11	11	11.39	0.39
270/8	object	CW	13	13	13.50	0.50
250/8	no object	TW	15	15	11.59	-3.41

FLIGHT DATE: 9-17-91

250/10	object	HW	5	5	10.97	5.97
250/10	no object	CW	8	8	13.32	5.32
250/10	object	TW	9	9	16.25	7.25
230/11	no object	HW	7	7	13.97	6.97
270/10	object	CW	7	7	13.97	6.97
270/10	no object	TW	6	6	11.59	5.59

FLIGHT DATE: 9-17-91

250/12	object	HW	12	12	13	1.00
250/12	no object	CW	15	15	15.68	0.68
270/12	object	TW	14	14	14.84	0.84

ACTUAL DATA FOR PILOT CHOICE MANEUVERS (continued)

270/12	no object	HW	13	13	14.19	1.19
280/10	object	CW	11	11	12.42	1.42
280/10	no object	TW	14	14	13.08	-0.92
FLIGHT DATE: 9-18-91						
120/5	object	HW	8	8	14.93	6.93
120/5	no object	CW	10	10	14.88	4.88
140/7	object	TW	12	12	19.00	7.00
140/7	no object	HW	9	9	14.16	5.16
140/7	object	CW	11	11	18.92	7.92
130/5	no object	TW	9	9	14.43	5.43
FLIGHT DATE: 9-18-91						
180/4	object	HW	9	9	8.91	-0.09
180/4	no object	CW	10	10	10.67	0.67
180/4	object	TW	13	13	13.27	0.27
160/5	no object	HW	10	10	10.76	0.76
160/5	object	CW	14	14	11.04	-2.96
180/8	no object	TW	15	15	13.43	-1.57
FLIGHT DATE: 9-19-91						
210	object	HW	12	12	12.67	0.67
240/12	no object	CW	10	10	10.94	0.94
240/12	object	TW	9	9	7.92	-1.08
240/12	no object	HW	10	10	10.44	0.44
240/12	object	CW	10	10	8.15	-1.85
240/12	no object	TW	8	8	5.74	-2.26
FLIGHT DATE: 9-19-91						
190/12	object	HW	5	5	11.59	6.59
190/12	no object	CW	6	6	6.68	0.68
210/9	object	TW	7	7	9.68	2.68
210/9	no object	HW	5	5	3.39	-1.61
211/2	object	CW	7	7	7.40	0.40
220/8	no object	TW	5	5	3.82	-1.18
FLIGHT DATE: 9-20-91						
350/12	object	HW	10	10	8.15	-1.85
350/12	no object	CW	5	5	3.92	-1.08
350/12	object	TW	4	4	3.69	-0.31
350/12	no object	HW	3	3	3.19	0.19
350/11	object	CW	5	5	4.53	-0.47
350/11	no object	TW	5	5	2.69	-2.31

ACTUAL DATA FOR PILOT CHOICE MANEUVERS (continued)

FLIGHT DATE: 9-20-91

010/14	object	HW	10	10	6.86	-3.14
010/14	no object	CW	12	12	9.86	-2.14
010/14	object	TW	11	11	10.19	-0.81
010/14	no object	HW	10	10	6.45	-3.55
020/10	object	CW	10	10	9.54	-0.46
020/10	no object	TW	13	13	10.51	-2.49

FLIGHT DATE: 10-01-92

340/10	object	HW	6	5.0	8.36	3.36
340/10	no object	CW	6	3.5	6.68	3.18
340/10	object	TW	6	4.0	9.85	5.85
330/10	no object	HW	6	1.0	2.99	1.99
330/10	object	CW	6	3.5	5.64	2.14
330/10	no object	TW	6	0.0	.21	.21

FLIGHT DATE: 10-02-92

280/04	object	HW	5	5.0	16.21	11.21
280/04	no object	CW	6	3.5	10.64	7.14
290/08	object	TW	6	5.5	11.10	5.60
290/08	no object	HW	6	5.0	10.66	5.66
290/08	object	CW	6	4.5	11.86	7.36
290/08	no object	TW	6	4.5	8.75	4.35

FLIGHT DATE: 10-02-92

250/11	object	HW	10	6.0	10.05	4.05
250/11	no object	CW	10	3.0	7.19	4.19
250/11	object	TW	10	6.0	5.43	-1.43
260/11	no object	HW	10	2.0	7.94	5.94
260/10	object	CW	10	6.0	5.02	-1.02
260/10	no object	TW	10	3.0	4.94	1.94

FLIGHT DATE: 10-05-92

040/12	object	HW	8	8.0	18.16	10.16
040/12	no object	CW	8	7.5	8.50	1.00
050/11	object	TW	8	6.0	9.87	3.87
050/11	no object	HW	8	6.0	4.97	-1.03
050/11	object	CW	8	7.0	7.97	.97
050/12	no object	TW	8	5.0	3.88	-1.12

FLIGHT DATE: 10-05-92

020/09	object	HW	6	6.0	11.10	5.10
020/09	no object	CW	6	1.0	7.36	6.36

ACTUAL DATA FOR PILOT CHOICE MANEUVERS (continued)

030/09	object	TW	6	4.0	10.59	6.59
030/09	no object	HW	6	1.0	4.69	3.69
050/09	object	CW	6	8.0	13.44	5.44
050/09	no object	TW	6	1.0	4.77	3.77
FLIGHT DATE: 10-07-92						
calm	object	HW	10	8.0	8.20	0.20
calm	no object	CW	6	4.0	1.78	-2.22
calm	object	TW	10	10.0	8.03	-1.97
calm	no object	HW	3	2.0	1.51	-0.49
270/05	object	CW	6	8.0	5.02	-2.98
270/05	no object	TW	6	6.0	3.25	-2.75
FLIGHT DATE: 10-07-92						
200/07	object	HW	10	20.0	21.21	1.21
200/07	no object	CW	10	8.0	15.37	7.37
200/07	object	TW	10	10.0	19.56	9.56
200/07	no object	HW	10	10.0	18.73	8.73
210/06	object	CW	10	8.0	13.91	5.91
210/06	no object	TW	10	10.0	16.70	6.70
FLIGHT DATE: 10-08-92						
180/10	object	HW	15	10.0	10.72	0.72
180/10	no object	CW	15	15.0	12.34	-2.66
170/07	object	TW	15	12.0	12.91	0.91
170/07	no object	HW	15	10.0	9.44	-0.56
180/10	object	CW	15	10.0	9.80	-0.20
180/10	no object	TW	15	11.0	9.25	-1.75
FLIGHT DATE: 10-08-92						
200/10	object	HW	6	6.0	8.00	2.00
200/10	no object	CW	6	2.0	3.99	1.99
160/10	object	TW	6	2.0	6.63	4.63
160/10	no object	HW	6	4.0	7.16	3.16
180/10	object	CW	6	4.0	9.73	5.73
180/10	no object	TW	6	2.0	10.30	8.30
FLIGHT DATE: 10-09-92						
160/15	object	HW	10	10.0	10.14	0.14
160/15	no object	CW	10	2.0	4.18	2.18
170/06	object	TW	10	8.0	7.07	-0.93
170/06	no object	HW	10	1.0	3.52	2.52
180/12	object	CW	10	7.0	7.46	.46
180/12	no object	TW	10	2.0	4.27	2.27

ACTUAL DATA FOR PILOT CHOICE MANEUVERS (continued)

FLIGHT DATE: 10-09-92

190/13	object	HW	8	8.0	14.50	6.50
190/13	no object	CW	8	2.0	5.53	3.53
180/13	object	TW	8	5.0	11.66	6.66
180/13	no object	HW	8	4.0	9.94	5.94
170/15	object	CW	8	5.0	12.70	7.70
170/15	no object	TW	8	3.0	7.94	4.94

FLIGHT DATE: 10-13-92

280/07	object	HW	10	8.0	10.45	2.45
280/07	no object	CW	10	8.0	7.42	-0.58
290/09	object	TW	10	10.0	4.60	-5.40
290/09	no object	HW	10	10.0	8.07	-1.93
310/09	object	CW	10	12.0	8.06	-3.94
310/09	no object	TW	10	12.0	7.65	-4.35

FLIGHT DATE: 10-14-92

120/04	object	HW	12	15.0	13.88	-1.12
120/04	no object	CW	12	10.0	7.02	-2.98
calm	object	TW	12	11.0	6.03	-4.97
calm	no object	HW	12	8.0	5.44	-2.56
130/05	object	CW	12	7.0	6.05	-0.95
130/05	no object	TW	12	8.0	5.47	-2.53

FLIGHT DATE: 10-15-92

290/04	object	HW	8	8.0	9.67	1.67
290/04	no object	CW	8	9.0	10.50	1.50
260/04	object	TW	8	10.0	11.53	1.53
260/04	no object	HW	8	10.0	12.02	2.02
270/05	object	CW	8	8.0	10.60	2.60
270/05	no object	TW	8	9.0	10.72	1.72

FLIGHT DATE: 10-15-92

270/07	object	HW	12	12.0	12.02	0.02
270/07	no object	CW	12	10.0	7.74	-2.26
270/05	object	TW	12	11.0	7.46	-3.54
270/05	no object	HW	12	10.0	7.28	-2.72
270/07	object	CW	12	12.0	11.02	-0.98
270/07	no object	TW	12	10.0	7.41	-2.59

FLIGHT DATE: 10-15-92

290/04	object	HW	20	6.0	23.09	17.09
290/04	no object	CW	20	10.0	23.64	13.64
calm	object	TW	20	3.0	18.66	15.66

ACTUAL DATA FOR PILOT CHOICE MANEUVERS (continued)

calm	no object	HW	20	8.0	19.46	11.46
240/06	object	CW	20	8.0	23.07	15.07
240/06	no object	TW	20	8.0	20.45	12.45
FLIGHT DATE: 10-16-92						
240/10	object	HW	10	10.0	16.88	6.88
240/10	no object	CW	10	12.0	16.41	4.41
240/11	object	TW	10	10.0	17.23	7.23
240/11	no object	HW	10	12.0	15.81	3.81
240/12	object	CW	10	10.0	16.70	6.70
240/12	no object	TW	10	12.0	15.34	3.34
FLIGHT DATE: 10-16-92						
240/14	object	HW	8	7.0	15.11	8.11
240/14	no object	CW	8	7.0	9.77	2.77
230/14	object	TW	8	6.0	7.95	1.95
230/14	no object	HW	8	8.0	8.78	0.78
260/18	object	CW	8	8.0	9.90	1.90
260/18	no object	TW	8	5.0	6.55	1.55
FLIGHT DATE: 10-19-92						
330/14	object	HW	12	12.0	14.07	2.07
330/14	no object	CW	12	11.0	11.42	0.42
340/12	object	TW	12	10.0	12.53	2.53
340/12	no object	HW	12	8.0	8.11	0.11
320/11	object	CW	12	10.0	13.85	3.85
320/11	no object	TW	12	9.0	7.78	-1.22
FLIGHT DATE: 10-20-92						
350/11	object	HW	12	10.0	21.05	11.05
350/11	no object	CW	12	15.0	21.28	6.28
350/09	object	TW	12	5.0	14.12	9.12
350/09	no object	HW	12	10.0	20.97	10.97
340/08	object	CW	12	10.0	16.93	6.93
340/08	no object	TW	12	5.0	15.09	10.09
FLIGHT DATE: 10-20-92						
340/07	object	HW	10	10.0	9.77	-0.23
340/07	no object	CW	10	5.0	17.88	12.88
360/07	object	TW	10	10.0	11.49	1.49
360/07	no object	HW	10	8.0	7.92	-0.08
320/07	object	CW	10	8.0	10.87	2.87
320/07	no object	TW	10	6.0	6.32	0.32

ACTUAL DATA FOR PILOT CHOICE MANEUVERS (continued)

FLIGHT DATE: 10-21-92

230/08	object	HW	6	6.0	14.35	8.35
230/08	no object	CW	6	5.0	13.20	8.20
240/13	object	TW	6	6.0	14.28	8.28
240/13	no object	HW	6	6.0	15.70	9.70
250/17	object	CW	6	8.0	12.61	4.61
250/17	no object	TW	6	6.0	11.13	5.13

FLIGHT DATE: 10-21-92

230/15	object	HW	8	7.0	12.42	5.42
230/15	no object	CW	8	7.0	8.60	1.60
210/13	object	TW	8	8.0	14.52	6.52
210/13	no object	HW	8	7.0	10.07	3.07
230/13	object	CW	8	10.0	12.69	5.69
230/13	no object	TW	8	7.0	10.60	3.60

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES

Actual Winds (ft)	Light/Object Condition	Wind Type	Safe Dist.(ft)	Estimated Dist.(ft)	Actual Dist.(ft)	Act/Est Calculated Perception Errors
FLIGHT DATE: 9-9-91						
calm	object	HW	10	10	8.26	-1.74
calm	no object	CW	10	9	5.79	-3.21
calm	object	TW	10	10	8.48	-1.52
calm	no object	HW	10	10	7.94	-2.16
calm	object	CW	10	10	9.86	-0.14
calm	no object	TW	10	10	7.72	-2.28
FLIGHT DATE: 9-9-91						
calm	object	HW	10	10	24.10	14.10
calm	no object	CW	10	10	20.85	10.85
calm	object	TW	10	10	17.96	7.96
calm	no object	HW	10	10	18.20	8.20
calm	object	CW	10	10	17.48	7.48
calm	no object	TW	10	10	17.49	7.49
FLIGHT DATE: 9-10-91						
230/12	object	HW	10	10	10.78	0.78
230/12	no object	CW	10	10	10.15	0.15
230/12	object	TW	10	10	7.01	-2.99
260/11	no object	HW	10	10	11.28	1.28
250/13	object	CW	10	10	8.53	-1.47
250/13	no object	TW	10	10	7.03	-2.97
FLIGHT DATE: 9-11-91						
299/3	object	HW	10	10	16.43	6.43
230/10	no object	CW	10	10	17.19	7.19
230/10	object	TW	10	10	16.68	6.68
320/8	no object	HW	10	10	17.74	7.74
320/8	object	CW	10	10	18.69	8.69
360/10	no object	TW	10	10	16.44	6.44
FLIGHT DATE: 9-11-91						
360/5	object	HW	10	10	15.61	5.61
360/5	no object	CW	10	10	18.70	8.70
360/5	object	TW	10	10	16.30	6.30
360/7	no object	HW	10	10	17.44	7.44
360/7	object	CW	10	10	17.28	7.28

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES (continued)

FLIGHT DATE: 9-12-91

050/5	object	HW	10	10	25.94	15.94
050/5	no object	CW	10	10	25.00	15.00
050/5	object	TW	10	10	21.97	11.97
040/7	no object	HW	10	10	23.33	13.33
040/7	object	CW	10	10	25.15	15.15
020/7	no object	TW	10	10	24.42	14.42

FLIGHT DATE: 9-12-91

030/6	object	HW	10	10	12.56	2.56
030/6	no object	CW	10	10	15.09	5.09
030/6	object	TW	10	10	15.53	5.53
040/5	no object	HW	10	10	12.44	2.44
040/5	object	CW	10	10	15.35	5.35
040/7	no object	TW	10	10	13.98	3.98

FLIGHT DATE: 9-16-92

280/10	object	HW	10	10	7.68	-2.32
280/10	no object	CW	10	10	10.26	0.26
280/10	object	TW	10	10	13.62	3.62
280/10	no object	HW	10	10	12.61	2.61
270/9	object	CW	10	10	12.31	2.31
270/9	no object	TW	10	10	10.40	0.40

FLIGHT DATE: 9-16-91

260/8	object	HW	10	10	18.11	8.11
260/8	no object	CW	10	10	16.07	6.07
260/8	object	TW	10	10	17.61	7.61
270/8	no object	HW	10	10	11.18	1.18
270/8	object	CW	10	10	10.43	0.43
250/8	no object	TW	10	10	8.08	-1.92

FLIGHT DATE: 9-17-91

250/10	object	HW	10	10	16.38	6.38
250/10	no object	CW	10	10	17.01	7.01
250/10	object	TW	10	10	19.24	9.24
230/11	no object	HW	10	10	12.21	2.21
270/10	object	CW	10	10	20.27	10.27
270/10	no object	TW	10	10	19.49	9.49

FLIGHT DATE: 9-17-91

250/12	object	HW	10	10	8.81	-1.19
250/12	no object	CW	10	10	9.09	-0.91

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES (continued)

270/12	object	TW	10	10	6.64	-3.36
270/12	no object	HW	10	10	8.75	-1.25
280/10	object	CW	10	10	6.73	-3.27
280/10	no object	TW	10	10	6.20	-3.80
FLIGHT DATE: 9-18-91						
120/5	object	HW	10	10	19.39	9.39
120/5	no object	CW	10	10	17.60	7.60
140/7	object	TW	10	10	18.17	8.17
140/7	no object	HW	10	10	16.62	6.62
140/7	object	CW	10	10	14.99	4.99
130/5	no object	TW	10	10	15.55	5.55
FLIGHT DATE: 9-18-91						
180/4	object	HW	10	10	14.35	4.35
180/4	no object	CW	10	10	14.18	4.18
180/4	object	TW	10	10	15.95	5.95
160/5	no object	HW	10	10	13.72	3.72
160/5	object	CW	10	10	11.10	1.10
180/8	no object	TW	10	10	13.67	3.67
FLIGHT DATE: 9-19-91						
210/12	object	HW	10	10	9.19	-0.81
240/12	no object	CW	10	10	8.70	-1.30
240/12	object	TW	10	10	8.26	-1.74
240/12	no object	HW	10	10	8.43	-1.57
240/12	object	CW	10	10	9.95	-0.05
240/12	no object	TW	10	10	7.69	-2.31
FLIGHT DATE: 9-19-91						
190/12	object	HW	10	10	17.43	7.43
190/12	no object	CW	10	10	9.45	-0.55
210/9	object	TW	10	10	16.19	6.19
210/9	no object	HW	10	10	12.12	2.12
211/2	object	CW	10	10	12.15	2.15
220/8	no object	TW	10	10	8.76	-1.24
FLIGHT DATE: 9-20-91						
350/12	object	HW	10	10	18.60	8.60
350/12	no object	CW	10	10	16.16	6.16
350/12	object	TW	10	10	11.44	1.44
350/12	no object	HW	10	10	14.42	4.42
350/11	object	CW	10	10	15.64	5.64
350/11	no object	TW	10	10	10.15	0.15

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES (continued)

FLIGHT DATE: 9-20-91

010/14	object	HW	10	10	9.17	-0.83
010/14	no object	CW	10	10	8.64	-2.36
010/14	object	TW	10	10	8.76	-1.24
010/14	no object	HW	10	10	2.92	-7.03
020/10	object	CW	10	10	7.42	-2.58
020/10	no object	TW	10	10	3.20	-6.80

FLIGHT DATE: 10-01-92

330/10	object	HW	10	10.0	23.11	13.11
350/09	no object	CW	10	8.0	21.07	13.07
350/09	object	TW	10	8.0	18.32	10.32
360/10	no object	HW	10	10.0	16.60	6.60
360/10	object	CW	10	10.0	17.70	7.70
360/10	no object	TW	10	10.0	16.44	6.44

FLIGHT DATE: 10-02-92

250/08	object	HW	10	9.0	21.11	12.11
250/08	no object	CW	10	11.0	19.78	8.78
250/08	object	TW	10	11.0	18.45	7.45
250/08	no object	HW	10	11.0	17.43	6.43
250/08	object	CW	10	12.0	21.01	9.01
280/08	no object	TW	10	11.0	15.27	4.27

FLIGHT DATE: 10-02-92

260/10	object	HW	10	10.0	16.52	6.52
260/10	no object	CW	10	10.0	18.73	8.73
260/12	object	TW	10	10.0	17.05	7.05
250/12	no object	HW	10	10.0	19.00	9.00
250/12	object	CW	10	10.0	11.69	1.69
250/12	no object	TW	10	10.0	14.27	4.27

FLIGHT DATE: 10-05-92

050/12	object	HW	10	10.0	13.93	3.93
050/12	no object	CW	10	10.0	9.80	-0.20
050/12	object	TW	10	10.0	10.90	0.90
050/15	no object	HW	10	9.0	7.88	-1.12
060/14	object	CW	10	10.0	10.61	0.61
060/14	no object	TW	10	10.0	10.32	0.32

FLIGHT DATE: 10-05-92

050/10	object	HW	10	10.0	15.49	5.49
050/10	no object	CW	10	10.0	15.61	5.61

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES (continued)

050/10	object	TW	10	10.0	17.29	7.29
050/10	no object	HW	10	10.0	15.06	5.06
060/13	object	CW	10	8.0	18.76	10.76
060/13	no object	TW	10	10.0	17.01	7.01
FLIGHT DATE: 10-07-92						
300/05	object	HW	10	12.0	10.05	-1.95
300/05	no object	CW	10	10.0	7.75	-2.25
310/04	object	TW	10	10.0	8.55	-1.45
310/04	no object	HW	10	10.0	7.04	-2.96
310/04	object	CW	10	8.0	7.31	-0.69
270/05	no object	TW	10	10.0	7.67	-2.33
FLIGHT DATE: 10-07-92						
230/06	object	HW	10	10.0	24.55	14.55
230/06	no object	CW	10	10.0	24.48	14.48
230/06	object	TW	10	10.0	22.76	12.76
290/04	no object	HW	10	10.0	22.58	12.58
290/04	object	CW	10	10.0	22.34	12.34
290/04	no object	TW	10	10.0	23.20	13.20
FLIGHT DATE: 10-08-92						
170/06	object	HW	10	10.0	11.83	1.83
170/06	no object	CW	10	12.0	10.31	-1.69
180/07	object	TW	10	10.0	7.67	-2.33
180/07	no object	HW	10	10.0	8.42	-1.58
180/07	object	CW	10	10.0	8.43	-1.57
180/07	no object	TW	10	10.0	7.93	-2.07
FLIGHT DATE: 10-08-92						
180/10	object	HW	10	7.0	12.45	5.45
180/10	no object	CW	10	6.0	12.50	6.50
160/10	object	TW	10	11.0	18.11	7.11
160/10	no object	HW	10	8.0	15.26	7.26
180/08	object	CW	10	12.0	19.52	7.52
180/08	no object	TW	10	8.0	18.60	10.60
FLIGHT DATE: 10-09-92						
180/17	object	HW	10	12.0	14.77	2.77
180/17	no object	CW	10	10.0	11.77	1.77
170/13	object	TW	10	10.0	13.55	3.55
170/13	no object	HW	10	10.0	13.90	3.90
170/12	object	CW	10	10.0	13.42	3.42
180/12	no object	TW	10	10.0	11.66	1.66

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES (continued)

FLIGHT DATE: 10-09-92

200/15	object	HW	10	8.0	18.11	10.11
200/15	no object	CW	10	8.0	18.00	10.00
210/14	object	TW	10	8.0	19.60	11.60
210/14	no object	HW	10	10.0	20.78	10.78
180/08	object	CW	10	9.0	21.61	12.61
0180/08	no object	TW	10	10.0	21.06	11.06

FLIGHT DATE: 10-13-92

310/07	object	HW	10	10.0	9.27	-0.73
310/07	no object	CW	10	10.0	13.49	3.49
310/08	object	TW	10	8.0	8.98	0.98
310/08	no object	HW	10	10.0	11.77	1.77
310/10	object	CW	10	10.0	13.86	3.86
310/10	no object	TW	10	10.0	11.90	1.90

FLIGHT DATE: 10-14-92

120/04	object	HW	10	10.0	6.09	-3.92
120/04	no object	CW	10	10.0	6.23	-3.77
calm	object	TW	10	9.0	3.90	-5.10
calm	no object	HW	10	7.0	2.88	-4.12
calm	object	CW	10	10.0	4.43	-5.57
calm	no object	TW	10	9.0	4.39	-4.61

FLIGHT DATE: 10-15-92

260/05	object	HW	10	10.0	12.36	2.36
260/05	no object	CW	10	10.0	13.86	3.86
280/04	object	TW	10	10.0	13.50	3.50
280/04	no object	HW	10	11.0	15.09	4.09
calm	object	CW	10	10.0	14.20	4.20
calm	no object	TW	10	11.0	11.77	0.77

FLIGHT DATE: 10-15-92

250/09	object	HW	10	10.0	18.75	8.75
250/09	no object	CW	10	10.0	17.25	7.25
270/06	object	TW	10	8.0	17.28	9.28
270/06	no object	HW	10	6.0	13.11	7.11
260/09	object	CW	10	8.0	15.91	7.91
260/09	no object	TW	10	9.0	15.39	6.39

FLIGHT DATE: 10-15-92

240/06	object	HW	10	10.0	17.17	7.17
calm	no object	CW	10	13.0	17.32	4.32

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES (continued)

calm	object	TW	10	10.0	14.21	4.21
calm	no object	HW	10	12.0	15.20	3.20
260/08	object	CW	10	10.0	15.94	5.94
260/08	no object	TW	10	10.0	13.70	3.70
FLIGHT DATE: 10-16-92						
240/10	object	HW	10	10.0	18.05	8.05
240/10	no object	CW	10	9.0	14.65	5.65
240/13	object	TW	10	10.0	18.58	8.58
240/13	no object	HW	10	10.0	17.48	7.48
240/12	object	CW	10	9.0	17.86	8.86
240/12	no object	TW	10	10.0	16.69	6.69
FLIGHT DATE: 10-16-92						
240/14	object	HW	10	10.0	17.80	7.80
240/14	no object	CW	10	10.0	15.90	5.90
260/16	object	TW	10	10.0	18.92	8.92
260/16	no object	HW	10	12.0	17.42	5.42
220/15	object	CW	10	12.0	21.69	9.69
220/15	no object	TW	10	10.0	12.84	2.84
FLIGHT DATE: 10-19-92						
320/14	object	HW	10	11.0	16.09	5.09
320/14	no object	CW	10	7.0	12.02	5.02
310/15	object	TW	10	11.0	15.70	4.70
310/15	no object	HW	10	11.0	10.63	-0.37
310/13	object	CW	10	10.0	16.16	6.16
310/13	no object	TW	10	9.0	12.00	3.00
FLIGHT DATE: 10-20-92						
340/07	object	HW	10	15.0	25.38	10.38
340/07	no object	CW	10	10.0	21.44	11.44
350/06	object	TW	10	12.0	21.53	9.53
350/06	no object	HW	10	8.0	13.03	5.03
350/07	object	CW	10	10.0	16.09	6.09
350/07	no object	TW	10	10.0	15.19	5.19
FLIGHT DATE: 10-20-92						
300/07	object	HW	10	10.0	12.49	2.49
300/07	no object	CW	10	10.0	13.63	3.63
330/05	object	TW	10	10.0	13.89	3.89
330/05	no object	HW	10	14.0	14.52	0.52
340/05	object	CW	10	12.0	14.90	2.90
340/05	no object	TW	10	10.0	12.85	2.85

ACTUAL DATA FOR REQUIRED 10-ft CLEARANCES (continued)

FLIGHT DATE: 10-21-92

250/13	object	HW	10	12.0	20.28	8.28
250/13	no object	CW	10	9.0	18.45	9.45
230/15	object	TW	10	10.0	17.08	7.08
230/15	no object	HW	10	8.0	18.11	10.11
250/10	object	CW	10	10.0	18.23	8.23
250/10	no object	TW	10	10.0	17.70	7.70

FLIGHT DATE: 10-21-92

230/14	object	HW	10	10.0	15.73	5.73
230/14	no object	CW	10	10.0	16.44	6.44
230/10	object	TW	10	12.0	19.76	7.76
230/10	no object	HW	10	10.0	16.69	6.69
250/10	object	CW	10	10.0	20.12	8.12
250/10	no object	TW	10	12.0	17.12	5.12

APPENDIX E

COMPARISON OF UH-1H AND R-22 TEST RESULTS

ACTUAL ROTOR TIP CLEARANCES REGARDLESS OF WIND DIRECTION

A COMPARISON OF UH-1H DAYTIME AND R-22 DAYTIME RESULTS

ACTUAL ROTOR TIP CLEARANCES REGARDLESS OF WIND DIRECTION- UH-1H
PILOT'S CHOICE
(TABLE 7 FROM REPORT FAA/CT-TN88/30)

In Feet

	With Obstacle	Without Obstacle
Mean	10.85	7.29
97.5 Percentile Point	26.87	19.47
N	48	60

ACTUAL ROTOR TIP CLEARANCES REGARDLESS OF WIND TYPE- R22
(PILOT PREFERENCE)
(TABLE 4 FROM THIS REPORT)

In Feet

	Without Obstacle	With Obstacle
Mean	10.02	12.10
SD	4.77	4.62
N	121	121

ACTUAL ROTOR TIP CLEARANCES BY WINDS - UH-1H
(TABLE 8 FROM REPORT FAA/CT-TN88/30)

In Feet

	Headwind	Crosswind	Tailwind
With Obstacle			
Mean	11.16	11.70	9.68
97.5 Percentile Point	25.18	30.76	22.44
N	16	16	16
Without Obstacle			
Mean	8.52	7.61	5.74
97.5 Percentile Point	24.04	18.66	13.86
N	20	20	20

NOTE: The 97.5 percentile point relates to + or - 2 standard deviations about the mean.

ACTUAL ROTOR TIP CLEARANCES BY WINDS - R22
(PILOT PREFERENCE)
(TABLE 5 FROM THIS REPORT)

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	9.94	10.84	9.26
SD	5.04	4.70	4.55
N	40	41	40
With Obstacle			
Mean	13.21	11.47	11.60
SD	4.44	4.64	4.70
N	41	40	40

PERCEPTION ERRORS

A COMPARISON OF UH-1H DAYTIME AND R-22 DAYTIME PERCEPTION ERRORS

PERCEPTION ERRORS - UH-1H
(TABLE 9 FROM REPORT FAA/CT-TN88/30)
(Actual Clearance - Pilot Estimated Clearance)

In Feet

	Headwind	Crosswind	Tailwind
With Obstacle			
Mean	3.04	2.70	.12
SD	6.57	9.13	5.61
N	16	16	16
Without Obstacle			
Mean	1.26	.86	-1.09
SD	8.48	6.43	4.42
N	20	20	20

PERCEPTION ERRORS
(TABLE 7 FROM THIS REPORT)
(Actual Clearance - Pilot Estimated Clearance)

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	2.49	2.78	1.90
SD	4.16	4.24	4.22
N	40	41	40
With Obstacle			
Mean	4.18	2.70	3.24
SD	4.60	4.47	4.98
N	41	40	40

A COMPARISON OF UH-1H DAYTIME AND R-22 DAYTIME PERCEPTION ERRORS

ACTUAL CLEARANCES WHEN ATTEMPTING 12-FOOT CLEARANCE- DAYTIME OPERATIONS UH-1H (TABLE 10 FROM REPORT FAA/CT-TN88/30)

	Headwind	Crosswind	Tailwind	Overall
With Obstacle				
Mean	14.37	14.24	13.49	14.03
SD	6.08	6.76	5.87	6.26
N	16	16	16	48
Without Obstacle				
Mean	14.10	13.40	12.55	13.55
SD	7.32	5.82	6.52	6.61
N	20	20	20	48

ACTUAL ROTOR TIP CLEARANCES REGARDLESS OF WIND TYPE WHEN ATTEMPTING 10-FOOT CLEARANCE - R-22 (TABLE 8 FROM THIS REPORT)

In Feet

	Without Obstacle	With Obstacle
Mean	13.96	15.13
SD	4.81	4.89
N	120	120

ACTUAL ROTOR TIP CLEARANCES BY WINDS WHEN ATTEMPTING 10-FOOT CLEARANCES- R22 (TABLE 9 FROM THIS REPORT)

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	13.78	14.76	13.34
SD	4.68	4.78	4.98
N	40	40	40
With Obstacle			
Mean	15.62	14.88	14.88
SD	5.09	4.92	4.75
N	40	40	40

PERFORMANCE ERRORS

A COMPARISON OF UH-1H DAYTIME AND R-22 DAYTIME PERCEPTION ERRORS

PERFORMANCE ERRORS - DAYTIME OPERATIONS - UH-1H
(TABLE 11 FROM REPORT FAA/CT-TN88/30)

In Feet

	Headwind	Tailwind	Crosswind
With Obstacle			
Mean	2.37	2.24	1.49
SD	6.08	6.76	5.87
N	16	16	16
Without Obstacle			
Mean	2.10	1.40	.55
SD	7.32	5.82	6.52
N	20	20	20

(Actual Clearance - 12 Ft)

PERFORMANCE ERRORS- R22
(TABLE 12 FROM THIS REPORT)

In Feet

	Headwind	Crosswind	Tailwind
Without Obstacle			
Mean	3.86	4.96	3.36
SD	4.61	4.87	4.99
N	40	40	40
With Obstacle			
Mean	5.47	4.88	4.93
SD	4.99	4.84	4.65
N	40	40	40

Actual Clearance - 10 ft

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